

5 DESIGN OF STEEL TRUSS FOOTBRIDGE

5.1 INTRODUCTION

A steel truss footbridge was selected in Section 3.7.3 as the best option for spans of 10 to 20m, and possibly up to 25m, when it is not possible to construct piers for intermediate supports for beam type footbridges. It should also be considered for spans over 10m when piers are possible. The advantages are considered to be:

- The steel sections needed should be available in main resource centres
- The sections are likely to be more uniform in shape and size than timber sections, allowing straightforward construction of standard truss designs
- Joints are easier to make than in timber trusses

It should be possible to construct a standard design in a medium sized workshop in convenient sized parts for transport to site. Assembly on site involves bolting the parts together and fitting a timber deck, tasks that can be carried out under supervision of a competent technician by local carpenters and others skilled in using their hands.

There are 3 levels at which the bridge may be broken down into parts for transportation:

1. Individual members that are predrilled in the workshop, transported and bolted together on site. An example is shown in Figure 5.1. In this case each piece had to be carried 24km from the road down a steep track to the footbridge site. This method requires considerable accurate drilling of holes in the workshop and careful assembly on site.
2. The steel members are cut and welded up into panels in the workshop and the panels drilled for bolting together. Panels are transported to site and bolted together on site. This significantly reduces pre-drilling and assembly work. Panels may weigh up to about 100kg.
3. Panels are bolted together in the workshop into modules that are transported to site. The modules are bolted together on site. This will require the least assembly work on site. Modules are likely to weigh up to 300 to 400kg and will be quite bulky to transport. This method is only likely to be possible if there is access for trucks directly to the footbridge site.

Level 2 is selected as the best compromise for ease of transport and least pre-drilling and assembly operations. Standard designs have therefore been developed for a modular steel truss footbridge which is made up as panels in a workshop and the panels transported to site and bolted together on site.

This option is suited to mainly flat to moderate rolling terrain. On steeper hilly paths and tracks it may be difficult to carry the panels and using option 1 above may be more practical.

The standard designs are described in this Chapter. The detailed design and construction of the footbridge is included in Appendix B. This includes step-by-step instructions for construction, and templates and jigs needed for accurate manufacture of the footbridge.



Members were carried individually 24km from the road down a steep track to the footbridge site.



The members being bolted together to form the modular truss footbridge

Figure 5.1: Transportation of Individual Members of a Steel Truss to Site and Assembly on Site

(Photographs from Bridges to Prosperity, the NGO that designed and supervised the installation of the footbridge)

5.2 DESIGN OF MODULAR STEEL TRUSS FOOTBRIDGE

Two basic designs have been developed based on the specifications of Figure 2.3 and the loads stated in Table 2.2.

1. A 1.4m wide footbridge with sides 1.5m high
2. A 2.1m wide footbridge with sides 1.8m high. The higher sides are to carry the larger loading on the 2.1m footbridge.

Standard layouts of panels are used for each design but panel lengths vary depending on the required span of the footbridge. Some members of the 2.1m wide footbridge are larger in section than for the 1.4 m wide bridge.

The standard design covers Spans of 10m (6 modules) to 20m (12 modules). An important factor is that **there must be an even number of panels** so that the left and right halves of the bridge are the same.

Three angle sections are used – 40 x 40 x6 mm; 50 x 50 x6 mm; 60 x 60 x6 mm. Small variations from these can be used. Gussets for the joints are made from 60 x 6 flat bar.

The method designed for bolting the modules together keeps bolt-hole diameters down to a size that should be within the drilling capacity of medium size workshops. M16 bolts are used on the 1.4m wide footbridge and M20 bolts are used on the 2.1m wide footbridge.

This Chapter describes the design concept and assembly. Step by step instructions for manufacture are contained in Appendix B.

5.2.1 Design Concept

The design concept is explained in [Figure 5.2](#) which shows the geometry of the panels and how they fit together. Note that the base panels overlap the end and side panels.

[Figure 5.3](#) shows the arrangement of the modules and the reference index used for the panels.

The number and lengths of modules for spans from 10 to 20m are listed in [Table 5.1](#). Note that since there must be an even number of side panels and there are half-length panels at each end, the number of full module lengths and base panels is always odd.

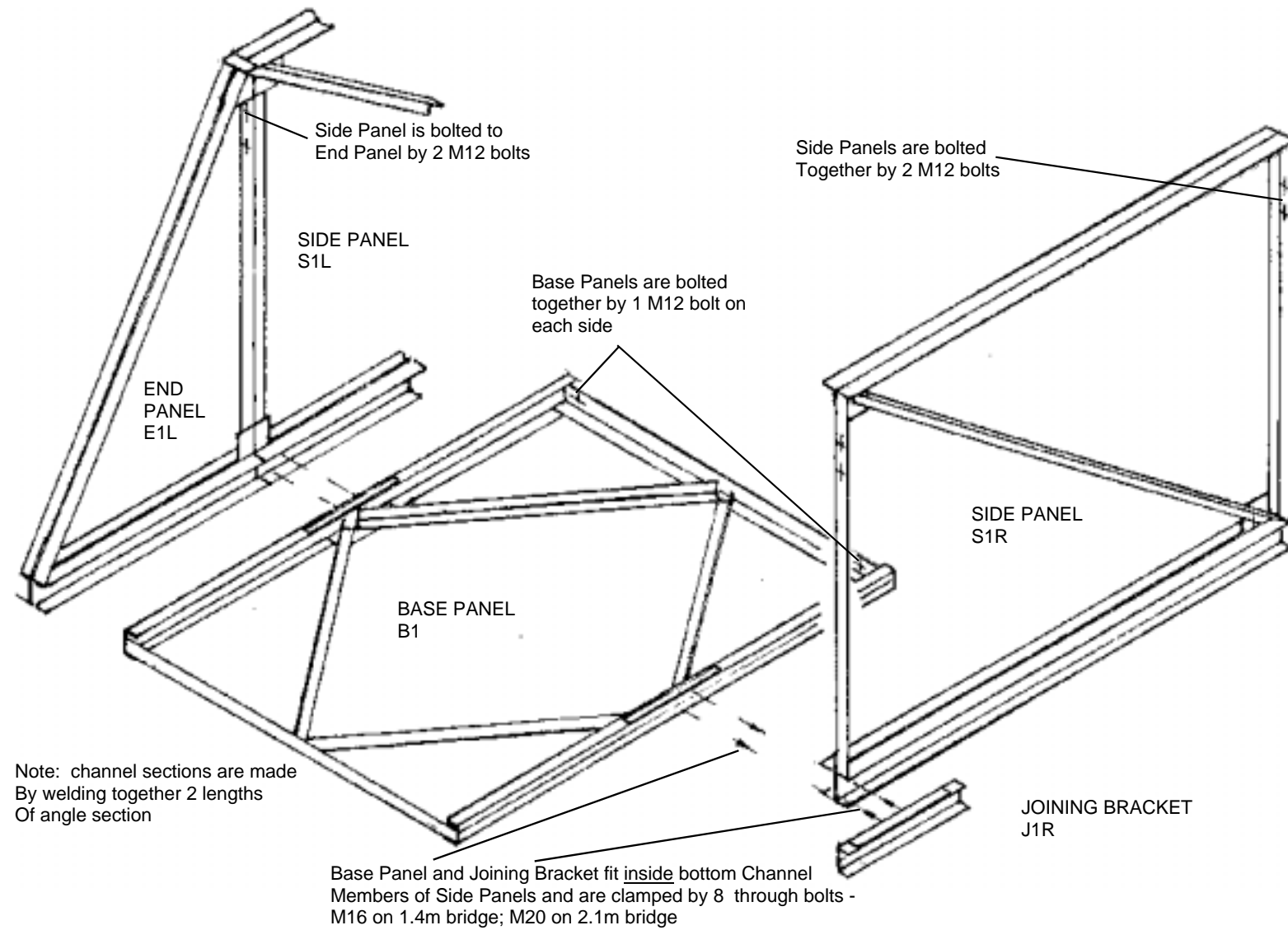
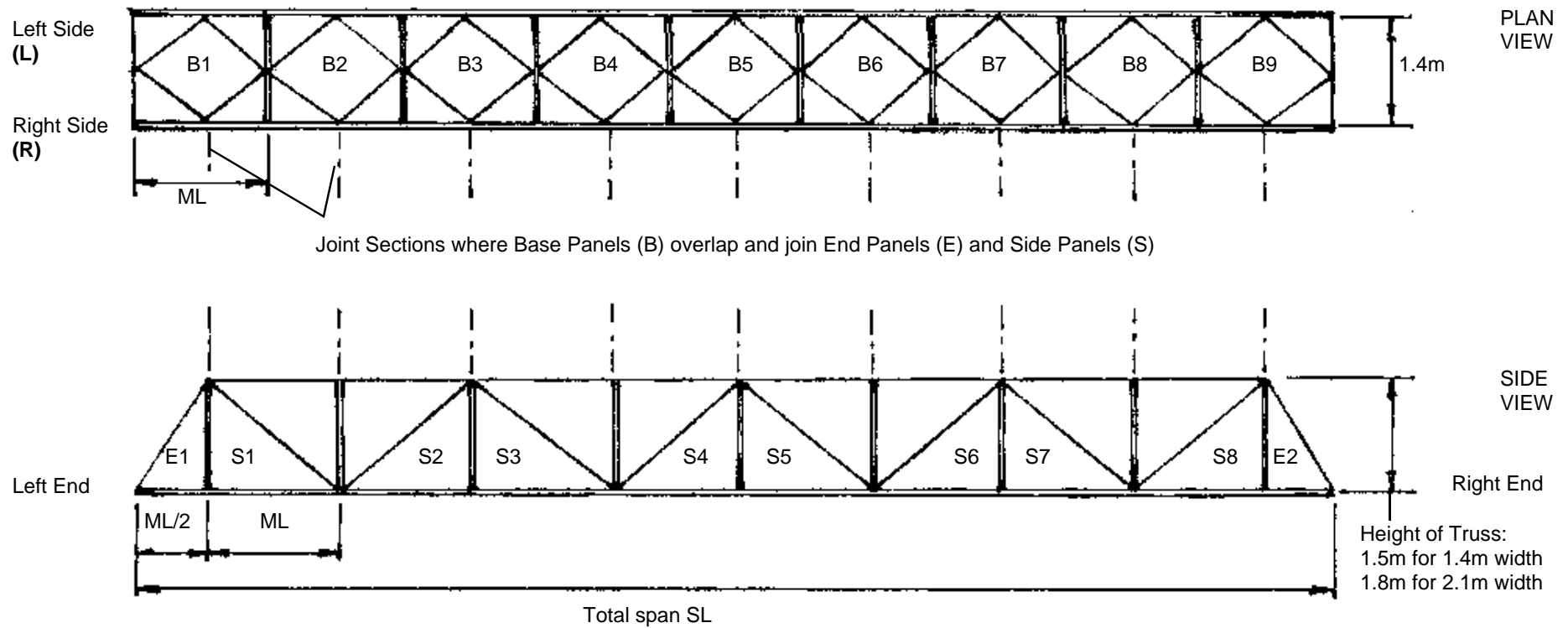


Figure 5.2: Details of Geometry and Assembly of Panels



- Panels Needed:
- End Panels (E) - 2 Left Side, 2 Right Side
 - Side Panels (S) - Even number; Note half have diagonal Top Left to Bottom Right
And half have diagonal Bottom Left to Top Right
 - Base Panels (B) - Number of side panels + 1

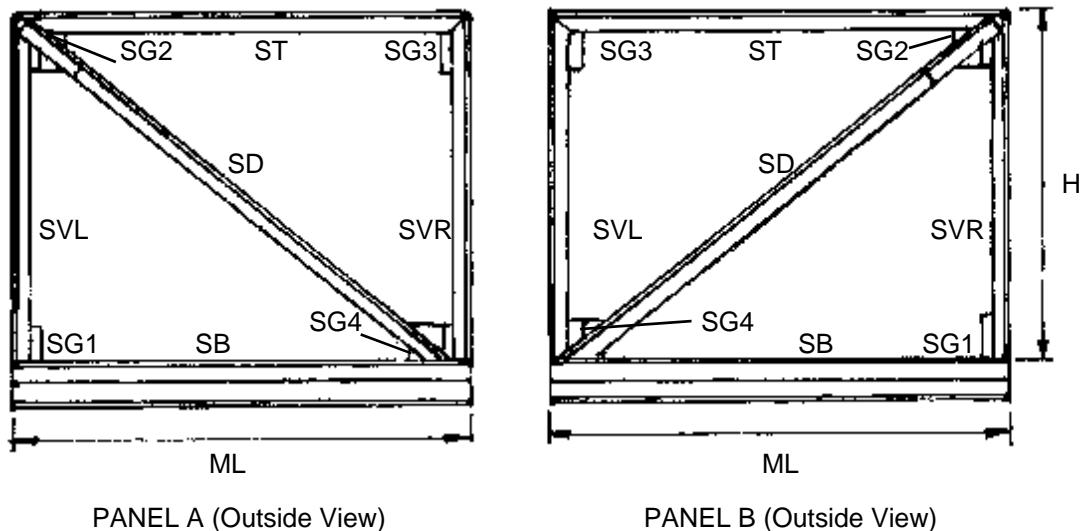
Figure 5.3: Details of Modular Design

Table 5.1: Numbers and Lengths of Modules for the Range of Spans

Span (m)	Number of Side Panels/side	Number of Base Panels	Length of Module (ML) m	Length of End Modules m
10	4	5	2.0	1.0
11	6	7	1.6	0.8
12	6	7	1.7	0.85
13	6	7	1.9	0.95
14	6	7	2.0	1.0
15	8	9	1.7	0.85
16	8	9	1.8	0.9
17	8	9	1.9	0.95
18	8	9	2.0	1.0
19	10	11	1.7	0.85
20	10	11	1.8	0.9

5.2.2 Details of Side Panels

Figure 5.4 shows the layout of the Side panels. Half have diagonals sloping from top left to bottom right (Panel A) and half bottom left to top right (Panel B).. The arrangement and numbering of side panels is shown in Figure 5.3. The dimensions, ML and H, are given in Table 5.1.



ML from Table 5.1

H = 1.5m for 1.4m width; 1.8m for 2.1m width

Figure 5.4: Members of Side Panels

The materials list for the 2 standard designs is given in Table 5.2.

Table 5.2: Materials List for Side Panels (per panel)

Member	Materials for 1.4m wide footbridge			Materials for 2.1m wide footbridge		
	Section	Length mm	Number	Section	Length	Number
Bottom Longitudinals (SB)	50x50x6mm angle	ML	4	60x60x6 mm angle	ML	4
Top Longitudinals (ST)	60x60x6mm angle	(ML – 12)mm (2)	2	60x60x6 mm angle	(ML – 12)mm (2)	2
Verticals (SVL & SVR)	50x50x6mm angle	1450mm	2	50x50x6 mm angle	1750mm	2
Diagonals (SD) (1)	50x50x6mm angle	Measure and fit	2	50x50x6 mm angle	Measure and fit	2
Gusset SG1	60x6 flat bar	220 mm	1	60x6 flat bar	240 mm	1
Gusset SG2	60x6 flat bar	120 mm	2	60x6 flat bar	120 mm	2
Gusset SG3	60x6 flat bar	120 mm	1	60x6 flat bar	120 mm	1
Gusset SG4	60x6 flat bar	220 mm	2	60x6 flat bar	240 mm	2
Spacer SS	60 x 6 flat bar	40mm	2	60 x 6 flat bar	40mm	2

Notes: (1) The outside of the panel should be welded up first and then the required length of the diagonals measured. The approximate lengths for material requirements are:

1.4m wide bridge – 2.23m for ML = 1.7m, to 2.48m for ML = 2.0m
 2.1m wide bridge – 2.45m for ML = 1.7m, to 2.66m for ML = 2.0m

(2) The length is 2 thicknesses of angle (2 x 6mm) less than ML to allow for the Vertical members at each end.

Design and Construction of Side Panels

Figure 5.5 shows the details of the design and construction of a side panel. This is a Panel A with diagonal running from Top Left to Bottom Right. For Panel B the diagonal runs from Bottom Left to Top Right and the gussets are moved to suit this.

The module length, ML, is obtained from Table 5.1 for the span of the footbridge. The section details and lengths are obtained from Table 5.2.

Details of the construction of the side panel members are given in Appendix B.

When the members have been manufactured, they need to be drilled and assembled in sequence as explained in Appendix B.

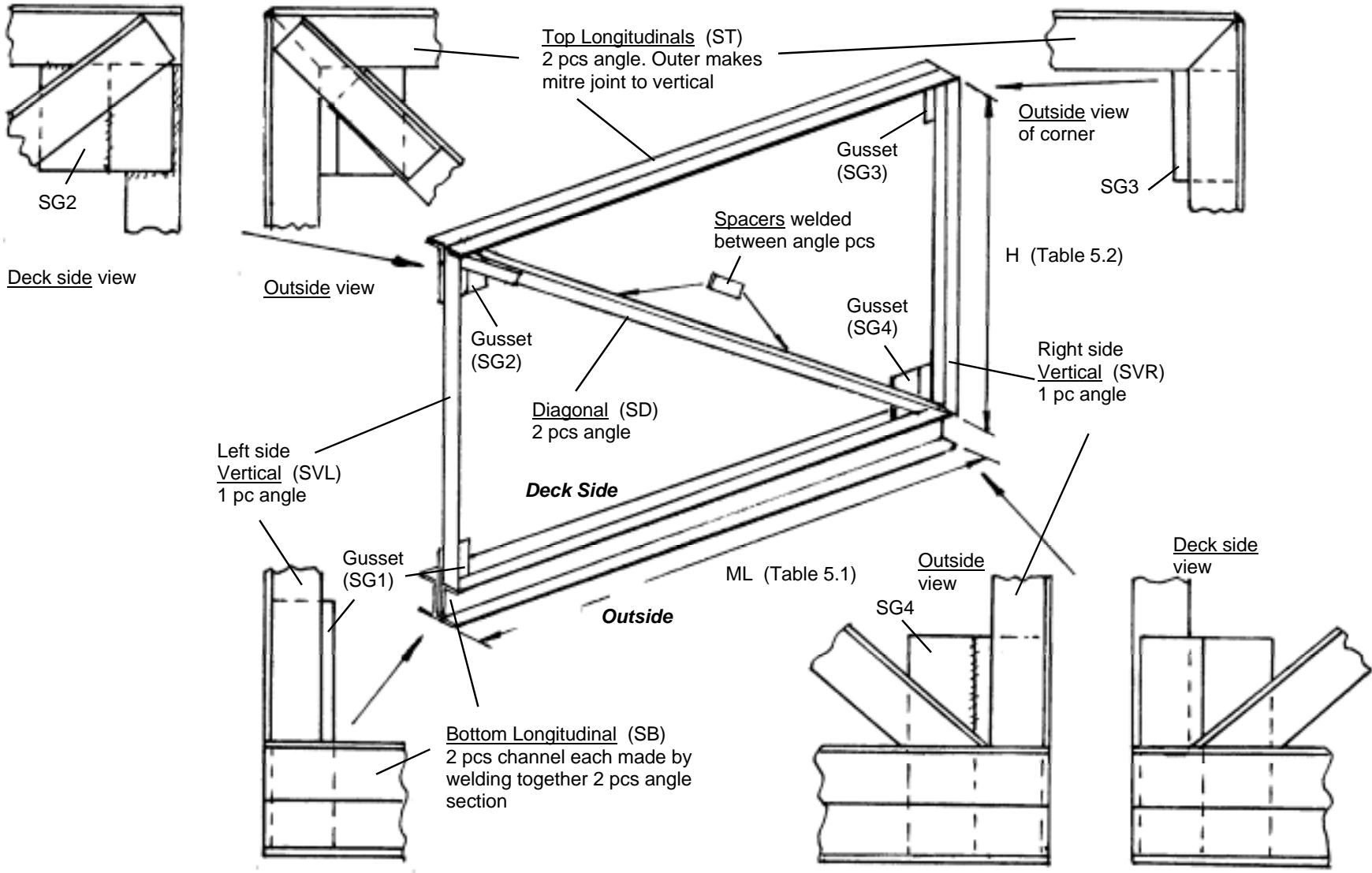


Figure 5.5: Design of Side Panel A (Panel B has SD bottom left to top right)

5.2.3 Details of End Panels

Figure 5.6 shows the details of the design of the end panels. Two pairs are needed, a left and right hand panel for each end. The one shown is a Right Side panel at the Left End of the bridge.

Table 5.3 shows the list of materials for an end panel.

Table 5.3: Materials List for End Panel (Single panel)

Member	1.4m Wide Footbridge			2.1m Wide Footbridge		
	Section	Length	Number	Section	Length	Number
Bottom Longitudinals (EB)	50x50x6mm angle	ML/2	4	60x60x6mm angle	ML/2	4
Vertical (EV)	50x50x6mm angle	1450mm	1	50x50x6mm angle	1750mm	1
Diagonal (ED)	50x50x6mm angle	Measure and fit (1)	2	60x60x6mm angle	Measure and fit	2
Gusset EG1	60x6 flat bar	210mm	1	60x6 flat bar	240mm	1
Gusset EG2	60x6 flat bar	260mm	1	60x6 flat bar	300mm	1
Gusset EG3	60x6 flat bar	220mm	2	60x6 flat bar	220mm	2
Gusset EG4	60x6 flat bar	180mm	1	60x6 flat bar	200mm	1

Note: (1) Weld the Vertical to the Base Longitudinal then measure up and cut the Diagonal to fit neatly into position. The approximate lengths for material requirements are:

1.4m footbridge – 1.68m for ML=1.7m to 1.77m for ML=2m
 2.1m footbridge – 1.95m for ML= 1.7m to 2.02m for ML = 2m

Details for the construction of the end panels are given in Appendix B.

The module length, ML, is obtained from Table 5.1 for the span of the footbridge. The section details and lengths are obtained from Table 5.3.

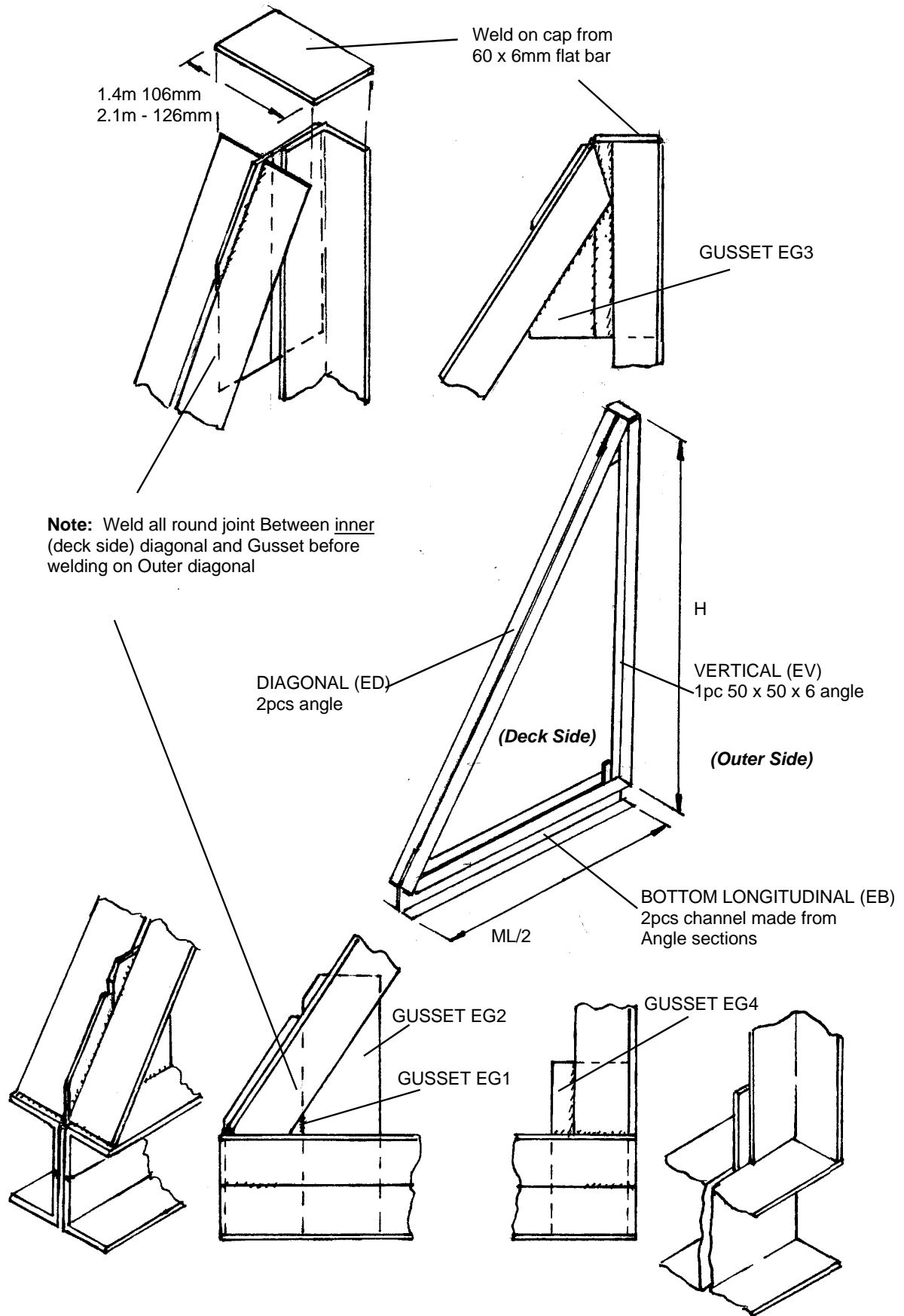


Figure 5.6: Details of Construction of End Panel (see Table 5.3 for materials)

5.2.4 Details of Base Panel

Figure 5.7 shows the design of the base panel.

Table 5.4 shows the list of materials for a Base Panel.

Table 5. 4: Materials List for Base Panel (Single panel)

Member	1.4m Wide Footbridge			2.1m Wide Footbridge		
	Section	Length	Number	Section	Length	Number
Bottom Longitudinals (BL)	40x40x6mm angle	ML	4	50x50x6mm angle	ML	4
Stiffeners for longitudinal	30x3 flat bar	500mm	4	40x3 flat bar	500mm	4
Diagonals (BD)	50x50x6mm angle	Measure and fit (1)	4	60x60x6mm angle	Measure and fit	2
Cross members (BC)	60x60x6mm angle	1486mm	2	60x60x6mm angle	2186mm	2
Gusset BG1	60x6 flat bar	200mm	2	60x6 flat bar	200mm	2

Note: (1) Weld the outside of the panel, longitudinal and cross members, then measure and cut the diagonals to fit. The approximate lengths for material requirements are:

1.4m footbridge – 1.1m for ML = 1.7m to 1.3m for ML = 2.0m
 2.1m footbridge – 1.3m for ML = 1.7m to 1.5m for ML = 2.0m

Details for the construction of the base panels are given in Appendix B.

The module length, ML, is obtained from Table 5.1 for the span of the footbridge. The section details and lengths are obtained from Table 5.4.

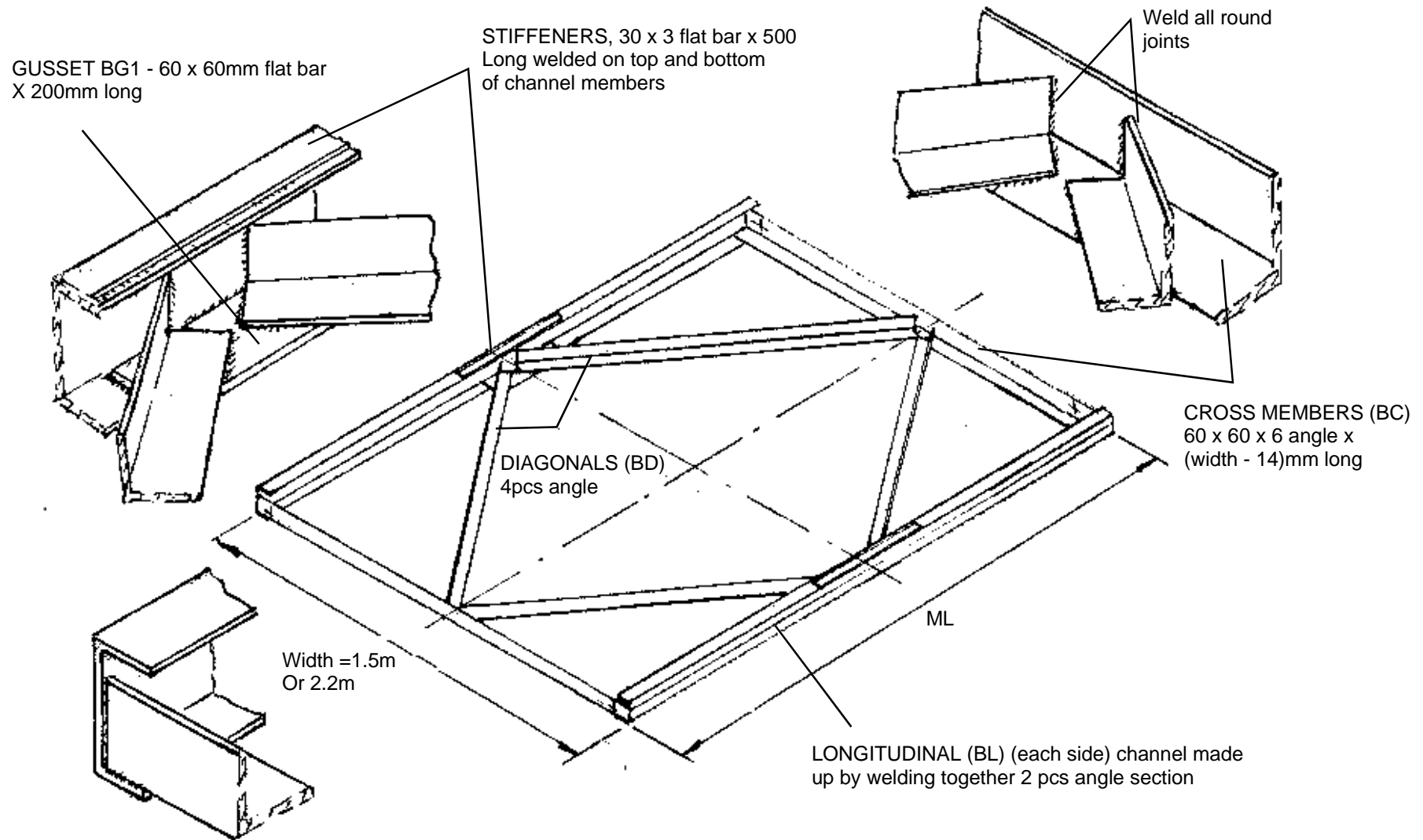


Figure 5.7: Details of Base Frame (see Table 5.4 for materials)

5.2.5 Details of Joining Bracket and Drilling Instructions

Figure 5.8 shows the details of the Joining Bracket and of drilling the holes for the bolts that bolt the panels and modules together.

The number of joining brackets needed = the number of side panels + 1 on each side

i.e. if there are 8 side panels/side, number of joining brackets/ side =9 and total for footbridge = $2 \times 9 = 18$

Table 5.5 gives the materials list for the joining brackets

Table 5. 5: Materials List for Joining Bracket

Member	1.4m Wide Footbridge			2.1m Wide Footbridge		
	Section	Length	Number	Section	Length	Number
Joining bracket	40x40x6mm angle	500mm	2	50x50x6mm angle	500mm	4
Stiffeners for bracket	30x3 flat bar	400mm	2	40x3 flat bar	400mm	2
Joining bolts/joint	M16	50mm	8	M20	50mm	8

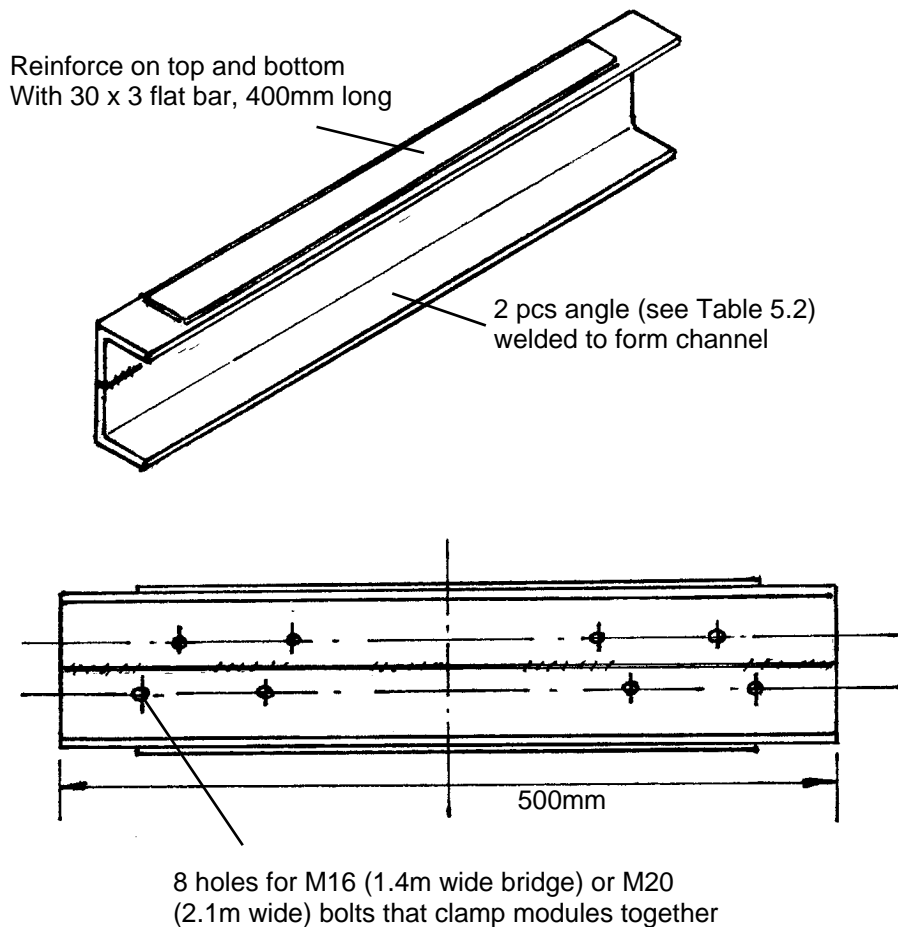


Figure 5.8: Joining Bracket (JL or JR)

5.2.6 Assembly and Welding of Panels

The footbridge modules are bolted together at 3 positions – bottom longitudinals of Side and End Panels; tops of Verticals; ends of cross-members of Base Panels.

To ensure that holes line up to bolt the modules together –

1. Parts must be clearly marked and kept in the same order as they were drilled
2. All the joints between adjacent modules must be bolted and lined up in an assembly jig before welding the members together. The panels must therefore be assembled and welded in sequence starting from the LH end.

Design of simple jigs for assembling 1.4m and 2.1m wide bridges are shown in Appendix B.

For ease of setting up and welding, the base panels should be completed first and then the 2 sets of side panels.

The assembly procedure is illustrated in Appendix B. The final assembly of an example of the modular steel truss footbridge is illustrated in Figure 5.9.

5.2.7 Assembly and Testing of Footbridge

Before transporting the footbridge to site it should be fully assembled in the workshop to make sure all panels bolt together without problems

When assembled the footbridge should be tested to its design load to check that it behaves satisfactorily and that its deflection is within the design limit (4mm/m span).

The preferred method of testing is by “crowd loading”, equivalent to 4 persons/m². Therefore, for a 1.4m wide footbridge the loading should be 6 persons/m and for a 2.1m wide footbridge 8 person/m.

5.2.8 Bracing of Vertical Posts

Each pair of vertical posts where the modules are bolted together on both sides of the footbridge are braced against side loads applied to the posts or top verticals by users of the footbridge.

Details of the bracing is shown in Figure 5.10. The angle braces are bolted to each end of a channel section cross-beam formed by welding 2 pieces of angle together. The cross-beams are clamped under the bottom longitudinals after the footbridge has been assembled.

5.2.9 Fixing of Footbridge on Abutments

It is important that the footbridge is securely fixed on the abutments but at the same time steel expands and contracts with changes in temperature. This must be allowed for in the method of fixing or the bridge may buckle. A suggested arrangement is shown in Figure 5.11. In this, one end of the footbridge is bolted down to the abutment while the other is prevented from moving sideways but allowed to slide longitudinally.



Details of construction and attachment of decking



Details of frame
(Note that braces for vertical are not yet fitted)

Figure 5.9: Illustration of Modular Steel Truss Footbridge

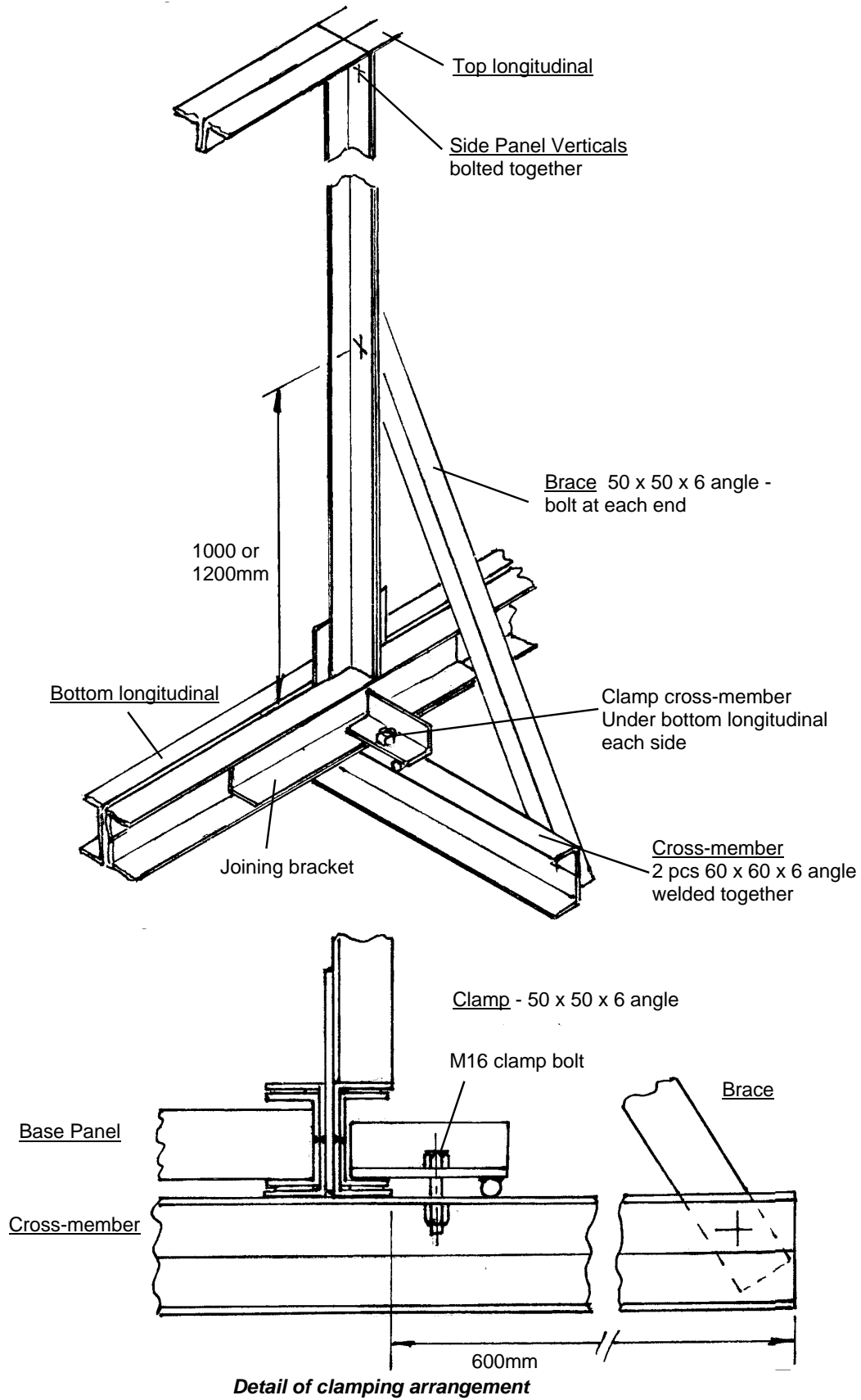
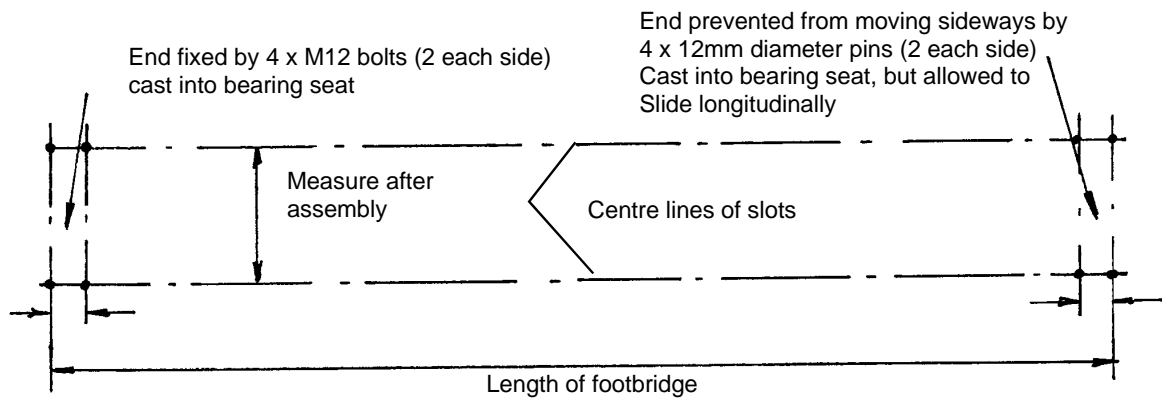
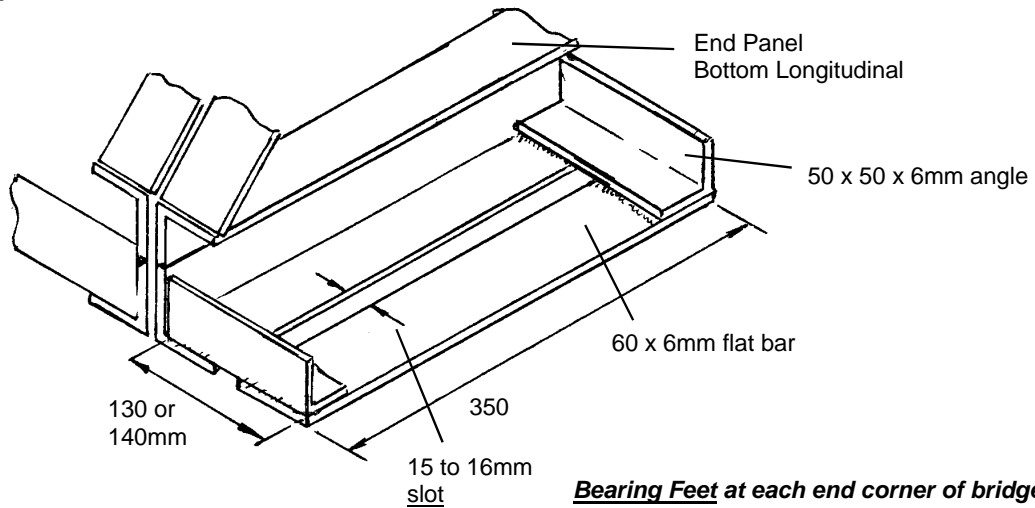


Figure 5.10: Detail of Side-Way Bracing of Side Panels
(Brace all vertical posts each side of bridge)



Locating the fixing bolts and pins accurately in the abutments is a problem. A method of overcoming this is to cast in the bolts and pins after the bridge is installed in position as shown below

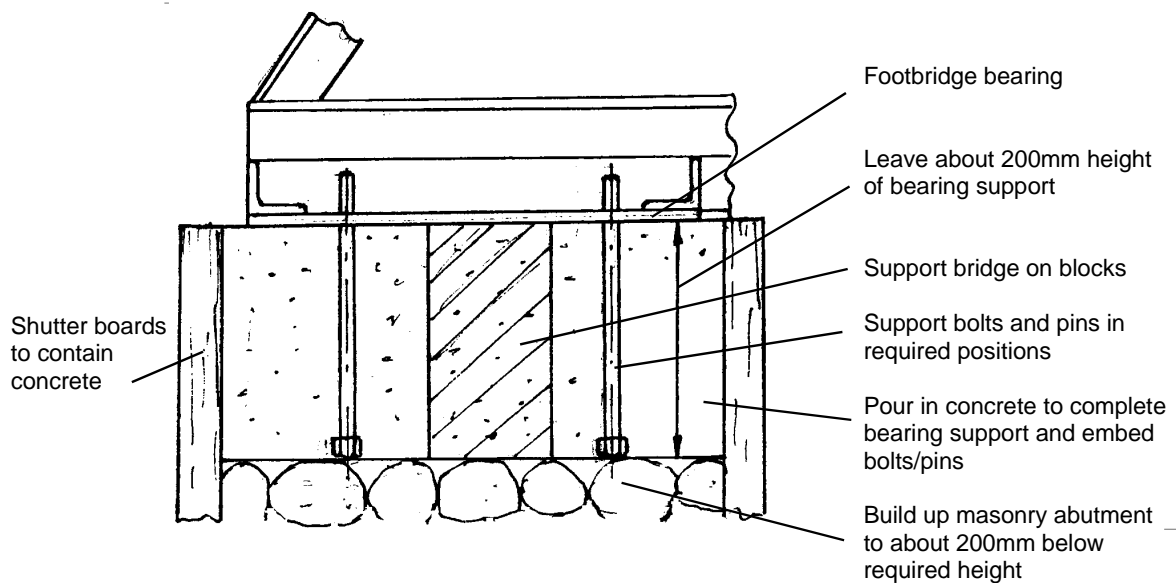


Figure 5.11: Bearing Supports and Anchors for Footbridge

5.2.10 Protective Treatment

The steel needs to be protected as effectively as possible against corrosion. The most effective method is galvanising all components but this treatment is unlikely to be available. The following treatment is therefore recommended before bolting together the panels:

1. On completion of welding the panels clean up all welds and weld splatter by grinding and wire brushing
2. Thoroughly wire brush all surfaces to remove scale and any rust
3. Paint all surfaces with a good quality, oil-based, anti-corrosion paint by spraying or brushing. This should comprise 3 coats – a primer/undercoat followed by 2 top-coats. Careful attention should be given to getting into all corners, inside drilled holes and sealing joints such as along the top longitudinals
4. A particular problem is to protect the inner surfaces between the channels of the bottom longitudinals of the end and side panels where there is only a 6mm gap. This can be achieved most successfully by spraying the paint. If this is not available a means of spreading the paint with an improvised brush having sufficiently long bristles or a suitable cloth or scraper blade that can be passed through the gap and pulled along the length of the gap should be used.

Bolts – ideally, plated bolts, nuts and washers should be used. If these are not available then the threaded and rounded section of the bolt should be coated with grease and the exposed head and nut painted after assembly

After installation all surfaces should be carefully inspected and any places where the paint has been damaged should be recoated.

5.2.11 Maintenance

The steelwork should be carefully inspected at intervals of about 1 year, paying particular attention to:

- Tightening of any bolts that have worked loose
- Repairing any areas of paintwork that have deteriorated
- Checking for any cracks around welded joints
- Cleaning out any soil or rubbish that has accumulated in corners, joints etc.

The footbridge should be completely repainted every 2 to 3 years.

5.3 DECKING

5.3.1 Design of Decking

Good quality hardwood planks should be used for the decking. It should be installed by competent local carpenters.

The cross planks are supported at each end on the bottom longitudinals of the end and side panels. Since the planks are not supported at the centre it is important to use planks that are strong enough to support the bridge user loads over the relatively long span between the longitudinals.

Because of the quite large sections of the cross planks it will probably be more economical to use these at spaced intervals to support smaller section longitudinal runners rather than to have a continuous deck of cross planks.

The recommended arrangement is shown in Figure 5.12. The required sections for the deck planks for the 1.4 and 2.1m wide footbridges are listed in Table 5.6 below.

Table 5.6: Timber Plank Sizes for Decking

Longitudinal Runners		Cross Beams			Kerb
Section Width x Thickness	Number across deck	Spacing (1)	Section Width x Thickness	Length	Section Width x Thickness
1.4m Wide Footbridge					
150x50mm	8 with gaps of about 11mm	600mm	150x75mm or 200x75mm	1.6m	150x50mm
2.1m Wide Footbridge					
150x50mm	12 with gaps of about 15mm	400mm	200x100mm or 150x125mm	2.3m	150x50mm
OR 150x75mm	12 with gaps of about 15mm	750mm	200x100mm or 150x125mm	2.3m	150x50mm

Note: (1) The spacing between cross-beams depends on the support needed for the longitudinal runners. Therefore increasing the section and strength of the longitudinal runners increases the spacing that can be allowed between the cross-beams.

5.3.2 Protective Treatment of Timber Decking

Protective treatment of the timber planks is likely to be limited to simple hand brushing methods. These are unlikely to achieve significant penetration into hardwood surfaces but may provide some protection. The methods suggested are:

1. Soaking the planks in a bath of engine sump oil or brushing on sump oil; or (2) Brushing on creosote.

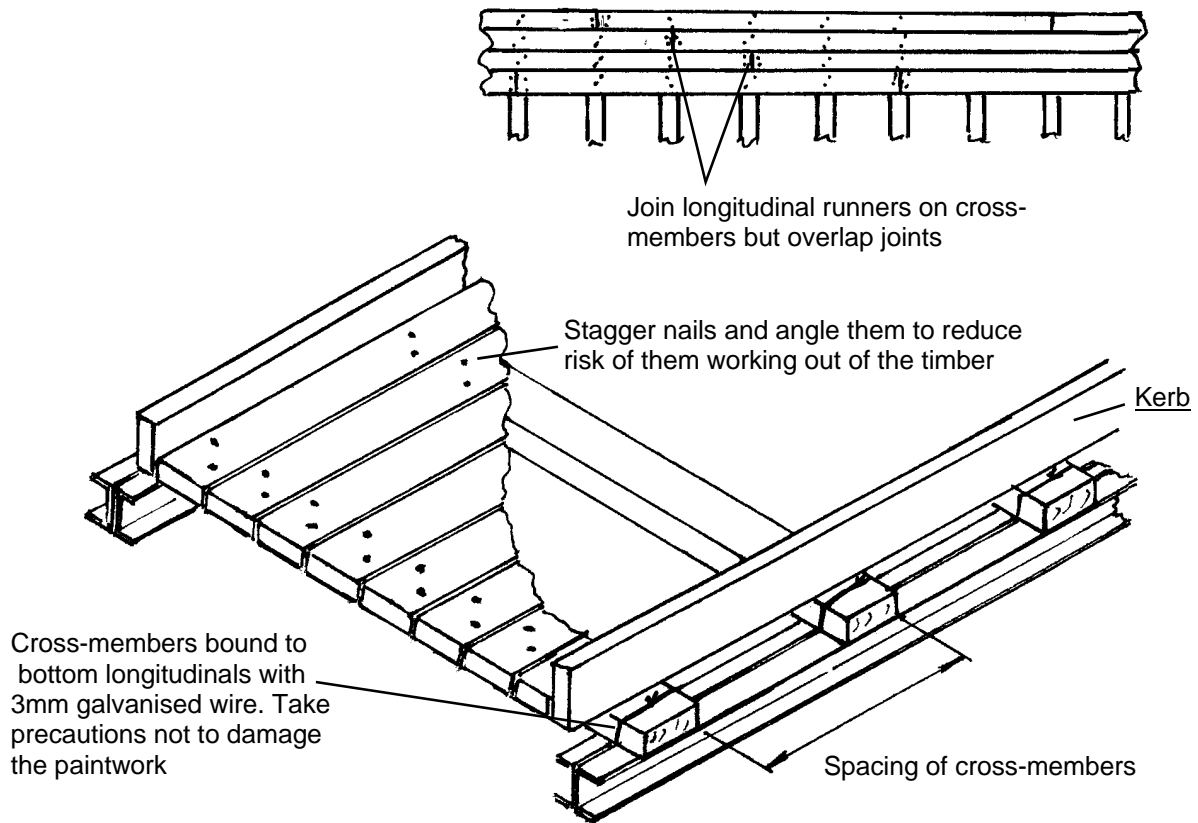


Figure 5.12: Details of Fixing Timber Decking

2. The end grains are the most vulnerable surface and could be protected with a coating of bitumen, such as bitumen paint.

5.3.3 Maintenance of Decking

The decking should be inspected every year. Loose nails should be hammered in and any planks that are significantly deteriorated or worn should be replaced. Exposed timber surfaces should be recoated at 12 month intervals.

5.3.4 Alternative Option Using Steel Plate

The timber deck will decay (rot) and need to be replaced several times during the life of the steel truss structure. It may therefore be worth considering a longer life alternative for the deck.

An alternative option is to use galvanised steel floor plates supported on steel cross-beams. A layout of this arrangement is shown in Figure 5.13.

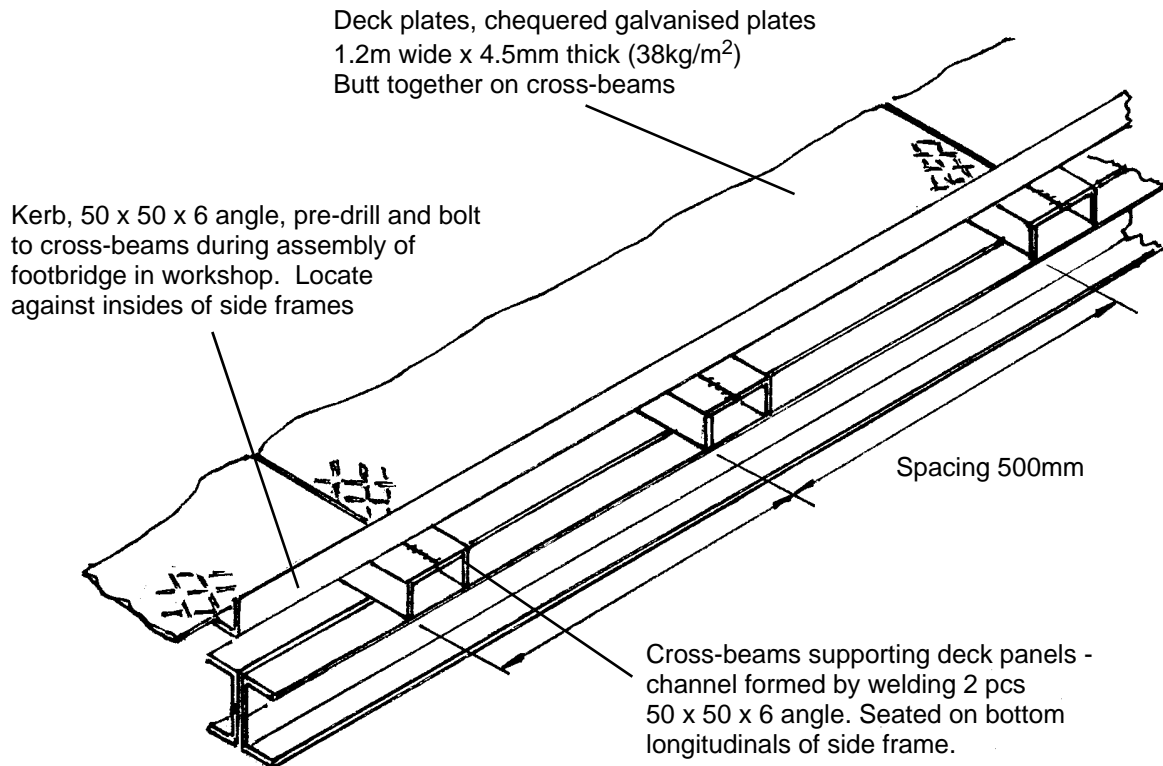


Figure 5.13: Alternative Option for Deck Using Galvanised Steel Floor Plates

Based on the material costs only and the assumed unit prices shown the estimated comparative costs of the timber and steel decks for a 1.4m wide footbridge are as follows:

Timber @ \$400/m³ – (\$3/m for 150 x 50 section) – cost/m = \$42

Steel @ \$0.60/kg (\$2.70/m for 50 x 50 x 6 angle) – cost/m = \$54.5

In each case the estimated weight of the deck is 80 to 85kg/m. The initial cost of the materials for the steel deck is seen to be about 25% higher than for the timber deck. But since it will probably last at least 3 times as long it has a much lower “Total Life” cost. Even if the unit price of timber is only half that shown the steel deck still has a slightly lower “Total Life” cost.

6 REINFORCED CONCRETE FOOTBRIDGES

6.1 INTRODUCTION

This type of bridge comprises basically a concrete slab reinforced with steel bars. Since concrete has a very low tensile strength, the primary steel bars are located near the bottom of the slab to carry all the tensile bending stresses. The concrete is assumed to carry all the compressive bending stresses.

The main advantages of reinforced concrete footbridges (RCC) are:

- All the materials needed – cement, sand, stone aggregate and steel bar – will be locally available in most locations
- For footbridges, the concrete can serve as the deck surface so that timber or other forms of decking are not needed
- The bridges have a long life and require little maintenance. Therefore, although their initial cost may be higher than other types, their “total life” cost will probably be lower

The main problems of local level construction of RCC footbridges are:

- The concrete slab has to be cast “in-situ” which requires considerable preparation work in setting up the formwork into which the concrete is poured. The dead weight of the concrete slab is high so that strong supports are needed for the formwork. Therefore, apart from quite short spans, props will be needed from the riverbed to support the formwork at intervals of 1 to 2 m so that RCC footbridges are only possible where the riverbed is suitable for this
- Setting up the steel reinforcement in the shutter boxes (boxes into which the concrete is poured) and the mixing and pouring of the concrete requires workers with appropriate skills and experience. These will probably have to be brought in from outside, increasing construction costs. It is possible that the formwork can be constructed by local carpenters under the supervision of an experienced technician.

The maximum unsupported span of RCC footbridges is about 12m. For longer spans intermediate pier supports will be needed. Therefore RCC footbridges can only be used for crossings of greater than about 10-12m width when the riverbed allows the construction of support piers. This will be mainly in areas of flat to moderate rolling terrain.

Within the limitations outlined above, RCC footbridges should be considered alongside other possible types. The main selection considerations are likely to be initial cost and whether the skilled and experienced labour needed is available. If neither of these factors rule out the use of RCC footbridges then they should be strongly considered because of their long life and low maintenance.

6.2 DESIGN OF REINFORCED CONCRETE FOOTBRIDGE

6.2.1 Plain Slab design

Figure 6.1 shows the layout of a RCC footbridge. The simplest design is a plain slab deck as shown in the figure. Other options such as a ‘T’ section (see Figure 6.5) or box section

will reduce weight and material costs but require more complex formwork and are therefore more difficult and costly to construct. For footbridges, the savings in weight and material costs are not likely to be great and therefore the simple plain slab type is recommended.

The section details for a range of spans from 4 to 10m are shown in [Figure 6.2](#). The primary reinforcement is the bottom axial reinforcement A and this increases with span as does the depth of the slab. Other reinforcement maintains the integrity of the slab but does not carry the bending load on the footbridge. The material properties assumed are at the bottom of the possible range so that the designs are quite conservative. Estimated quantities of materials for the various spans are shown in Table 6.1.

Table 6.1: Estimated Quantities of Materials for RCC Footbridge

Span m	Depth of Slab mm	Volume of concrete m ³	Bags of cement (50kg)	Length of reinforcing bar (m)		
				20 (1) or 25 (2)mm	12 mm	10mm
1.4m wide footbridge						
4	180	1.6	10	45 (1)	60	95
6	240	2.9	18	100 (1)	90	140
8	320	5.0	30	120 (2)	115	190
10	400	7.6	46	200 (2)	145	240
2.1m wide footbridge						
4	180	2.2	14	65 (1)	75	120
6	240	4.1	25	150 (1)	110	175
8	320	7.1	43	175 (2)	145	235
10	400	10.9	66	295 (2)	180	300

Details of the bearing supports for the RCC footbridge are shown in [Figure 6.3](#). If the span of the footbridge is greater than about 10m intermediate pier supports will be needed. Concrete or masonry abutments and piers should be used to give a life compatible with that of the footbridge. Concrete bearing caps are cast onto the top of the abutments and piers. The attachment is reinforced with steel dowels cast into the masonry and concrete. At ONE END ONLY of the footbridge deck these dowels extend into the deck slab to locate the footbridge on the bearing supports. At the other end the deck slab should be free to move.

Details of an arrangement for attaching safety handrails are shown in [Figure 6.4](#). The posts are attached by bolting to anchor brackets cast into the sides of the concrete deck. The method allows the prefabrication of parts in a workshop and assembly on site. It is important to use a method of attaching the rails that does not require the accurate location of posts. In the figure timber rails that can be drilled on site are bolted to the posts. An alternative arrangement is to clamp lengths of the 50x50x6mm angle section to the posts using U-bolts fitted through predrilled holes in the posts.

Steps in Construction

1. Locate and mark out positions of abutments (and of piers if these are needed) as indicated in Appendix A
2. Excavate footings and construct abutments and piers (if needed) to designs shown in Figures 7.4 and 7.8 respectively. The steel dowels should be cast into the tops of the abutments and piers as shown in Figure 6.3

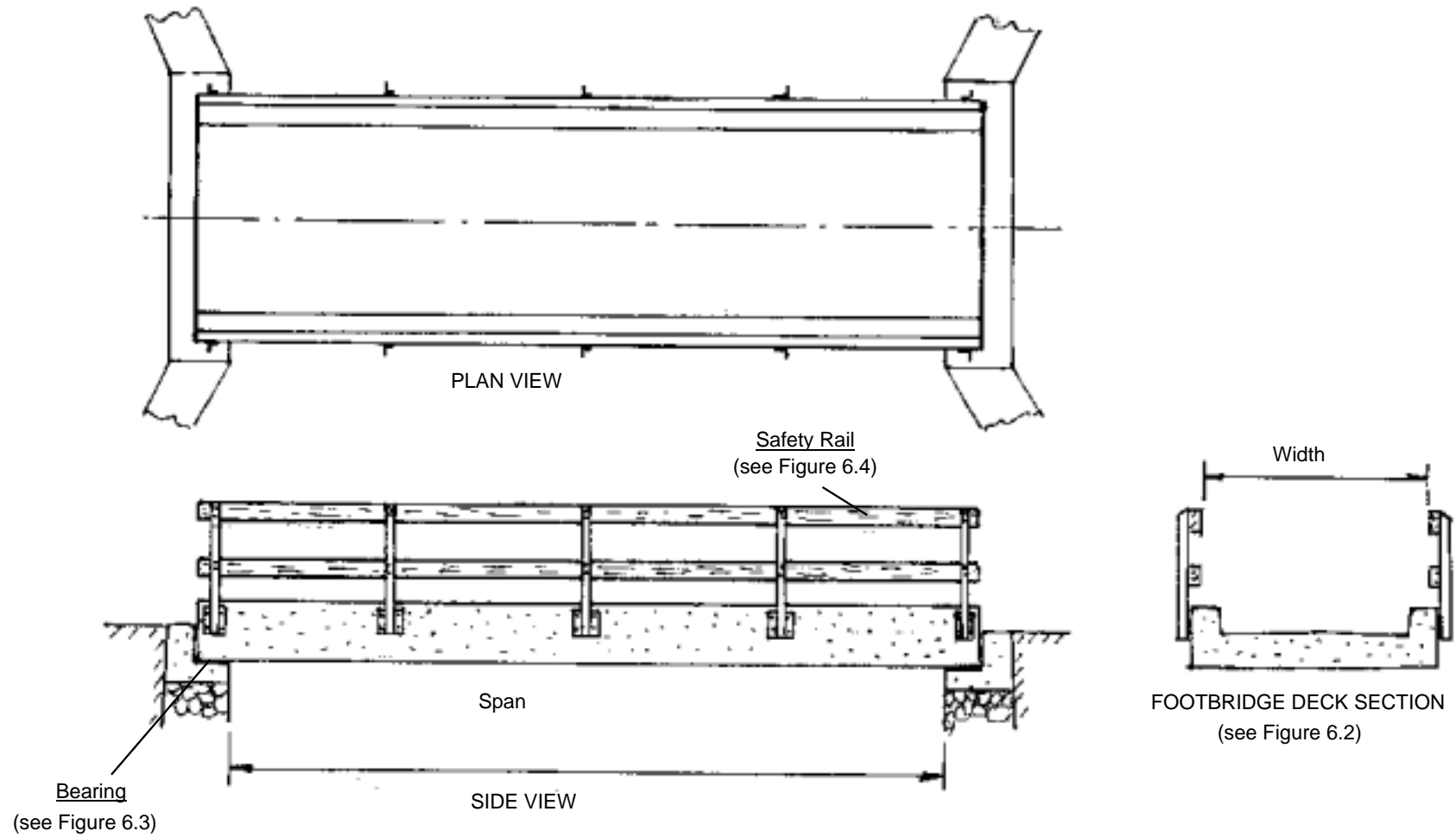
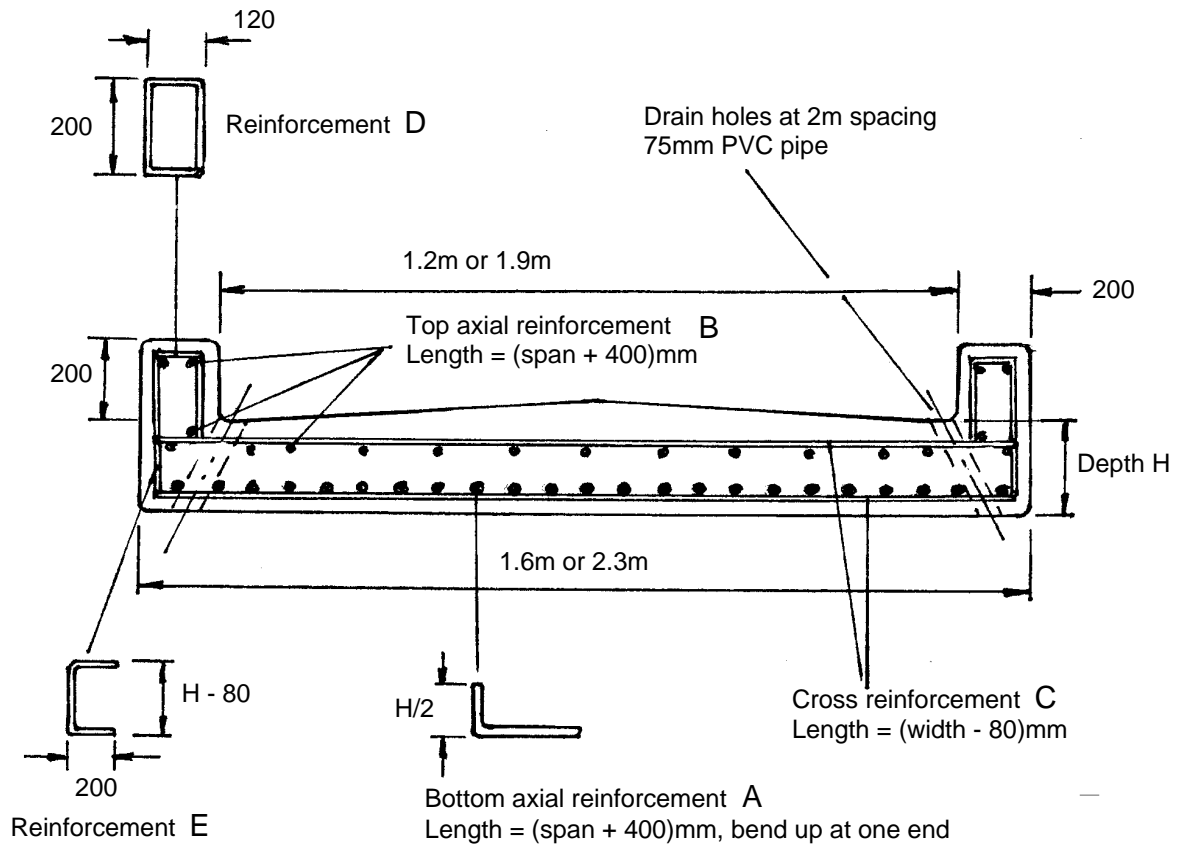


Figure 6.1: Layout of Reinforced Concrete Footbridge

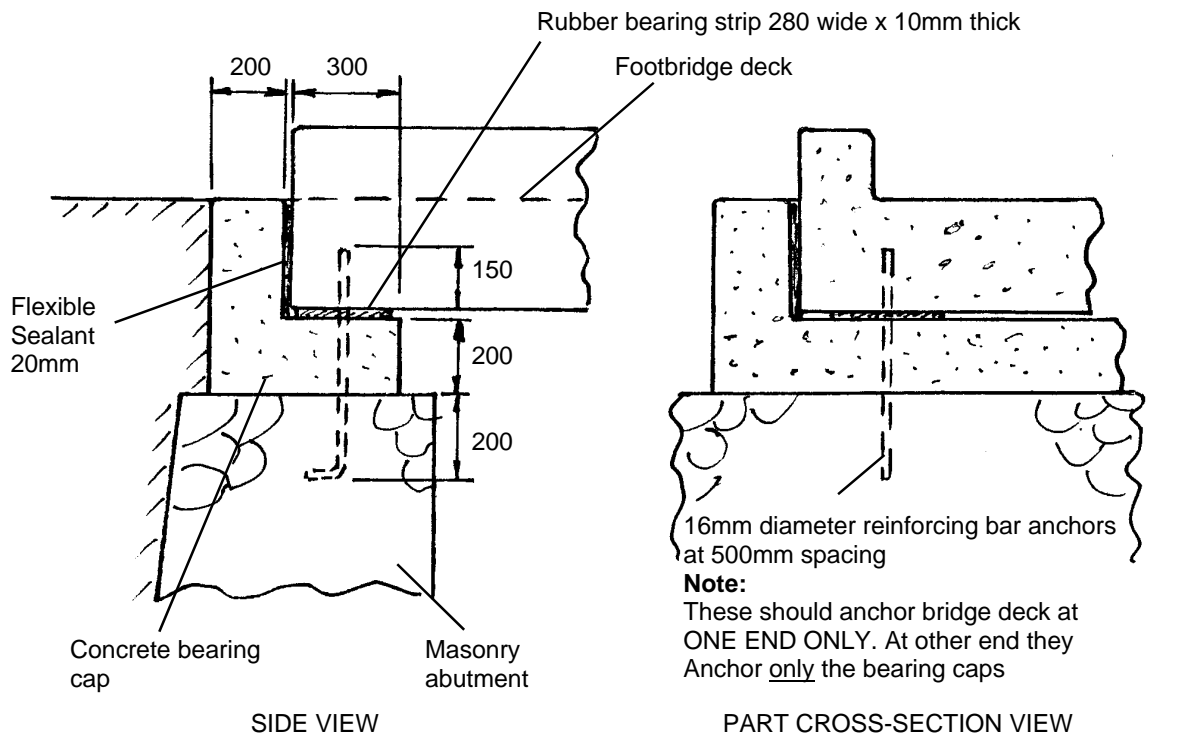


Span M	Depth Hmm	Details of Steel Reinforcement – Size @ Spacing (mm)				
		A	B	C	D	E
4	180	20 @ 160	12 @ 200	10 @ 250	10 @ 250	10 @ 250
6	240	20 @ 100	12 @ 200	10 @ 250	10 @ 250	10 @ 250
8	320	25 @ 110	12 @ 200	10 @ 250	10 @ 250	10 @ 250
10	400	25 @ 80	12 @ 200	10 @ 250	10 @ 250	10 @ 250

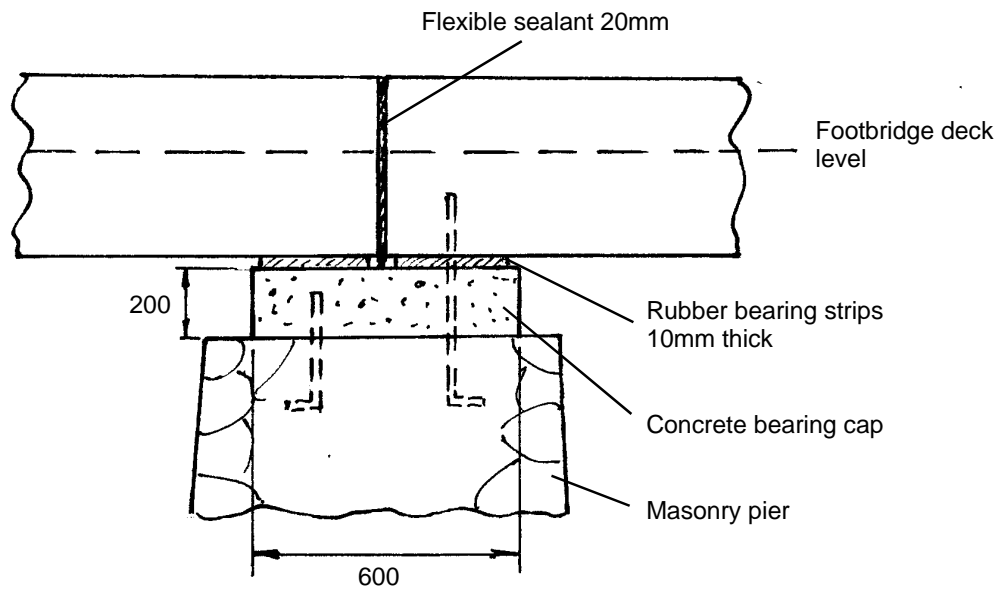
Specifications:

- Concrete mix 1:2:4 with maximum aggregate size of 20mm – assumed minimum strength 17N/mm²
- Reinforcing steel – mild steel bar with minimum yield strength 210N/mm²
- Single lengths of reinforcing bar but if 2 lengths needed the minimum overlap should be 50 x diameter
- Minimum thickness of cover of reinforcement is 40mm

Figure 6.2: Sections of Plain Slab Reinforced Concrete Footbridges



(a) Abutment Bearing



(b) Pier Bearing

Figure 6.3: Details of Bearing Supports for RCC Footbridge

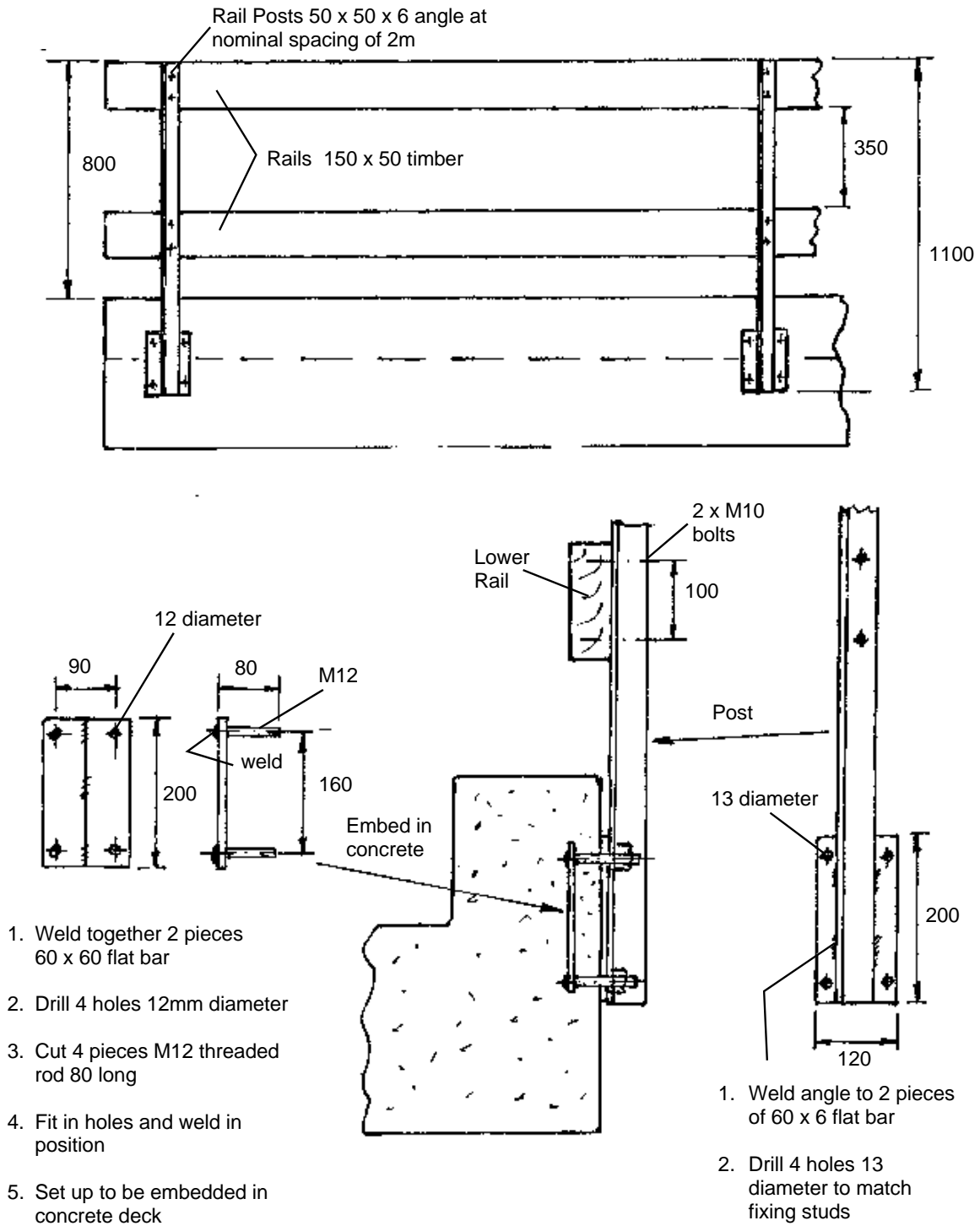
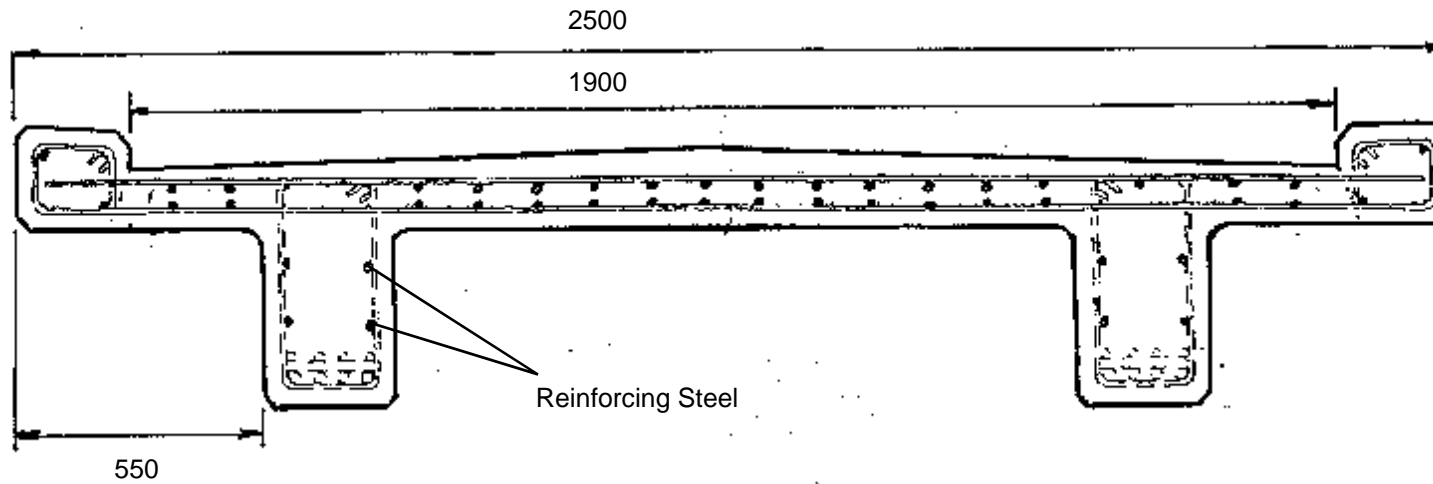


Figure 6.4: Attachment of Safety Rail to Deck of RCC Footbridge

3. Use blockboard and/or timber planks to construct the shutter boxes for the concrete bearing caps as shown in Figure 6.3. Timber poles may be used to prop the boxes in position
4. Mix and shovel concrete into the shutter boxes. Tamp it in to ensure it is densely packed with no air holes. Leave for 7 days, keeping damp with wet bags, and then remove shuttering
5. Construct the shutter box for the deck slab using lengths of timber. The box members should be securely supported and all joints should be free from gaps that might allow escape of the concrete. The box should be supported between its ends by T-shaped timber pole or post props located at 1 to 2m intervals. The inside faces of the box should be coated with oil to prevent sticking of the concrete
6. Cut and shape the reinforcing steel bars as shown in Figure 6.2. Use spacer blocks made from mortar to fix the reinforcing bar in position. Make sure there is a minimum gap of 40mm between the steel bars and the sides of the box to give the specified concrete cover of the steel. Spacer bars cut from the bar may be used to accurately locate the upper and lower layers of reinforcement. Where pieces of bar cross or join the joints should be securely bound with galvanised wire. Also locate the anchor brackets for the handrail posts in position. The steel bar should be cleaned to remove oil, dirt and flaking rust that could reduce the bond strength with the concrete
7. Mix the concrete to the specification shown in Figure 6.2, using a container to measure out the proportions accurately rather than shovels. Sand and stones should be clean and free from organic materials. Mixing should be on a clean, firm surface, not earth, to avoid contamination of the concrete. Note it is important to use the correct proportion of water to cement of 0.55 to 1 to achieve the required strength. If too much water is used the aggregate will sink and reduce the strength of the concrete
8. Mixing and transport of the concrete should be well organised to enable the whole slab to be cast in one continuous operation. Walkways should provide access to all parts of the slab. The concrete should be tamped to produce a dense structure and levelled with shovels and lengths of timber
9. When the slab is completed it should be kept damp for 7 to 14 days with wet bags to allow proper curing of the concrete to produce the required strength. The slab should not be walked on for at least 5 days
10. Once the slab has cured the formwork can be removed. The prefabricated rail posts can then be bolted in position and the rails attached.

6.2.2 Beam Section Design

In this design the primary bending strength is provided by reinforced concrete beams that are integral with a deck slab of reduced thickness compared to a plain slab. A typical section is shown in Figure 6.5 taken from standard designs used by the Ministry of Works in Malawi. Because of the deep beams this is a more efficient section, saving in weight and cost of concrete. The estimated saving of a standard 8m long slab compared with a plain slab design is about 15%. However, the formwork for the beam section design is more complex to construct and set up.

**Notes:**

1. All dimensions in mm
2. Drawing NOT TO SCALE
3. Design should only be adapted by qualified engineer

Figure 6.5: Typical Section for a Reinforced Concrete 'T' Beam Footbridge

7. INSTALLATION OF FOOTBRIDGES

7.1 INTRODUCTION

This Chapter deals with the installation of footbridges. It covers the following:

- 7.2 Construction of abutments for supporting the ends of the footbridge, including bearing arrangements
- 7.3 Construction of piers for providing intermediate support to the footbridge
- 7.4 Procedures for erecting the footbridge
- 7.5 Notes on the organisation of the work

7.2 ABUTMENTS

The location of abutments is covered in Appendix A. Factors to be considered in the design and construction of the abutments include:

- The soil characteristics and allowable bearing pressure to determine the minimum contact area or footing area of the abutment on the soil
- The stability of the soil – Appendix A defined a maximum slope of the bank at the location of the abutments of 60° for stable rock down to 35° or less for soft soil and gravel. In the latter case piles may be needed and anchors to stabilise the abutment
- The flood level in relation to the abutments and whether protective measures are needed to counter erosion of the bank around the abutments
- The bearing area of the abutment where the footbridge is supported, especially for timber footbridges
- The arrangements for fixing the footbridge in position so that it is not easily washed away.

7.2.1 Selection of Type of Abutment

The long-term sustainability of any bridge is largely dependent on the strength and stability of its abutments. The proper selection, design and construction of abutments are therefore critical to the life of the bridge.

The forms of construction include:

1. Existing rocks: if suitably large and stable rocks are available on the banks of the stream/river they can be used as abutments. Masonry or concrete can be used to build up an even bearing seat for the footbridge.
2. Timber: either timber logs or sawn timber beams may be used depending on availability. Logs will be cheaper. The bearing sill may rest on the ground or may be raised by supporting it on posts sunk into the ground.
3. Masonry: if suitably large stones are locally available they can be bound together with mortar to produce a relatively low-cost and long-life abutment.
4. Mass concrete: this is plain concrete without steel reinforcement. A larger section and therefore more concrete is needed than for reinforced concrete.
5. Reinforced concrete: this involves a more complex construction and the need for experienced workers

Selection:

Existing rocks: provide a low-cost, long-term solution but with limited situations where it is possible.

Selection from the other types will depend mainly on the type of footbridge, the availability and cost of materials and soil conditions. Selection considerations are outlined in Table 7.1

Table 7.1: Selection of Type of Abutment

Footbridge Type	Considerations in Selecting Abutment	Preferred Type of Abutment
1. Steel and RCC	<ul style="list-style-type: none"> Replacing an abutment is very difficult. Its life should therefore be at least equal to that of the footbridge structure. <u>Timber</u> abutments are therefore not considered appropriate. If suitable stones are available, <u>Masonry</u> is preferred to <u>Concrete</u> for lower cost. 	<ol style="list-style-type: none"> Masonry Mass Concrete Reinforced Concrete
2. Timber	<ul style="list-style-type: none"> Timber will probably require installation of posts in the ground. This may not be practical on rocky or stoney ground. Masonry and concrete will require excavation of footings requiring significant labour inputs. Masonry and concrete may initially be more costly but will probably be cheaper in the long-term. It will probably be possible to use the same abutments when the footbridge has to be replaced. 	<ol style="list-style-type: none"> Masonry Depends on soil conditions and local availability and cost of materials.

7.2.2 Building an Abutment on Existing Rocks

It will probably be necessary to build on top of the rock to raise the level of the bearing surface and/or provide a level bearing seat. This may be done with masonry and/or concrete depending on how much the seat has to be raised.

It is important to achieve a good key between the added material and the existing rock. The surface of the rock should be roughened up with a hammer and chisel or sledgehammer and possibly holes made to insert pieces of reinforcing bar to be embedded in the concrete/masonry cap. This is illustrated in Figure 7.1.

7.2.3 Timber Sill Abutments

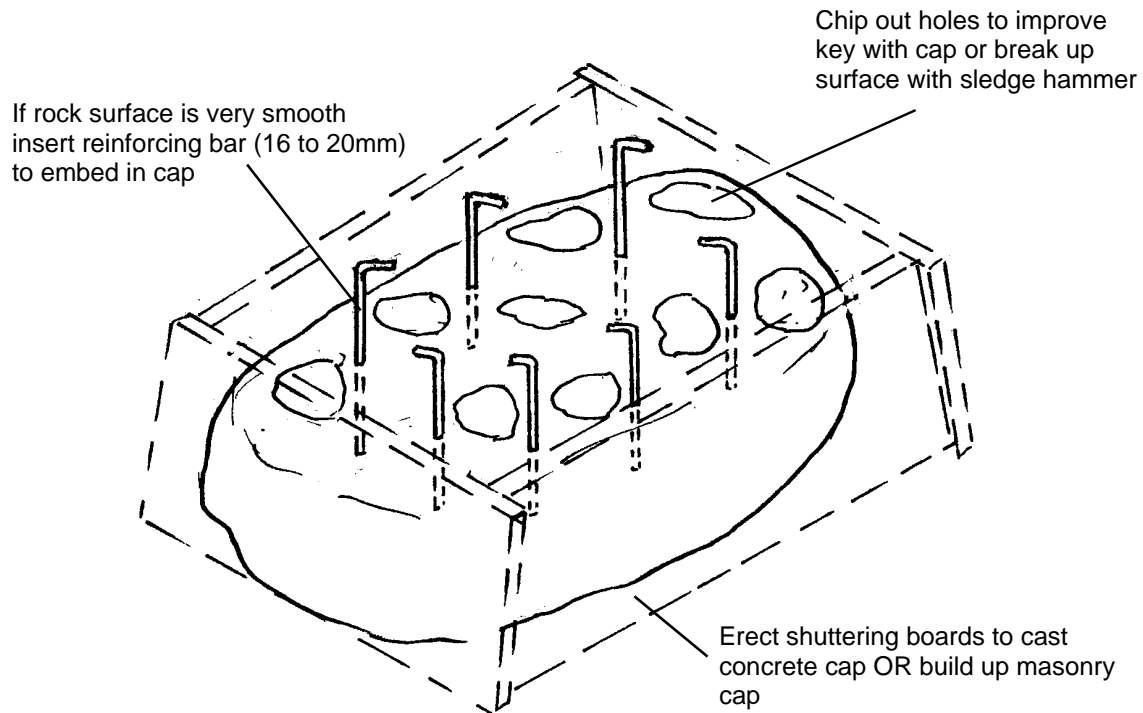
If the height of the abutment and bank soil conditions are suitable, the simplest form of abutment is a timber log or beam sill resting directly on the ground. It may be necessary to excavate the ground to provide a flat, well-drained seat for the sill.

The construction of timber sill abutments is shown in Figure 7.2. The sill may be a log or sawn timber beam. It is important to make sure there is enough bearing area between the stringers and sill to support the load on the footbridge. This is not a problem for sawn timber beams if the correct sizes are used but grooves need to be cut in the top surface of log sills to give adequate contact area with the stringers. A guide on the area needed is given in Figure 7.2.

Sawn timber stringers may also be supported on log sills. In this case flats will need to be cut into the top of the sill to provide adequate bearing area.

The sill must be securely fixed in position on the bank and the stringers secured to the sill. In Figure 7.2 this is achieved by driving posts into the bank around the sill and binding the sill to the posts with galvanised wire. The stringers in turn are bound to the sill.

Timber sills will have limited durability, but a number of steps can be taken to prolong their life:

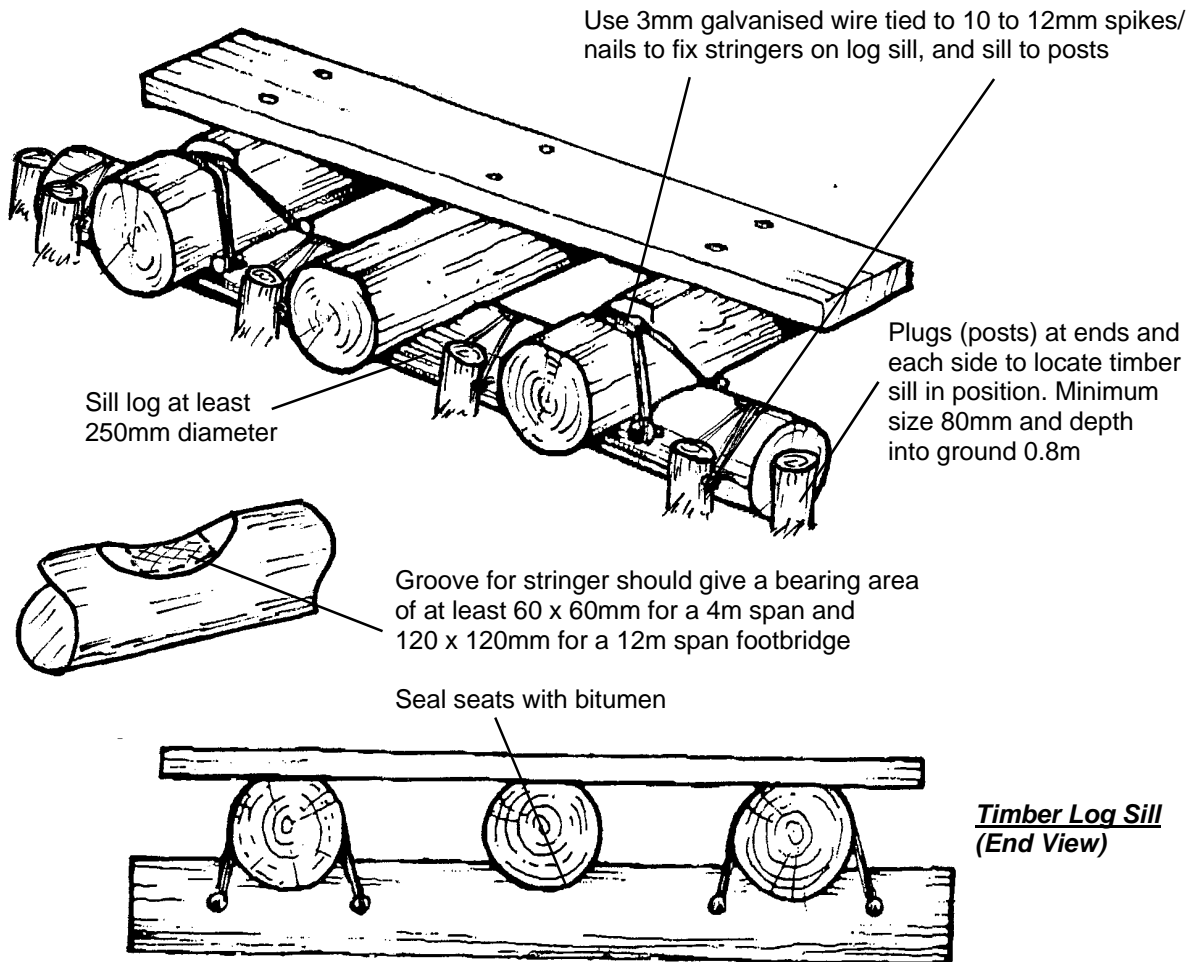
**Note:**

A number of adjacent rocks could be used. Rocks should be stable and firmly embedded in the ground.

Figure 7.1: Constructing an Abutment on Existing Rock(s)

- Use good quality hardwood
- Seat the sills on a bed of stones or rocks to drain away water and prevent contact with moist soil. A layer of geotextile material could be used if available.
- Seal the bearing area between stringer and sill with bitumen to exclude water
- Seal the ends of the sill and tops of the posts with bitumen and coat other surfaces with creosote or engine sump oil.

The ends of the deck stringers resting on the sills should be separated from contact with soil by a barrier of sheet steel, timber or a masonry wall as shown in Figures 4.10 to 4.12.



Note: It is best to seat the sills on a bed of stones to prevent contact with moist soil and reduce risk of sill rotting

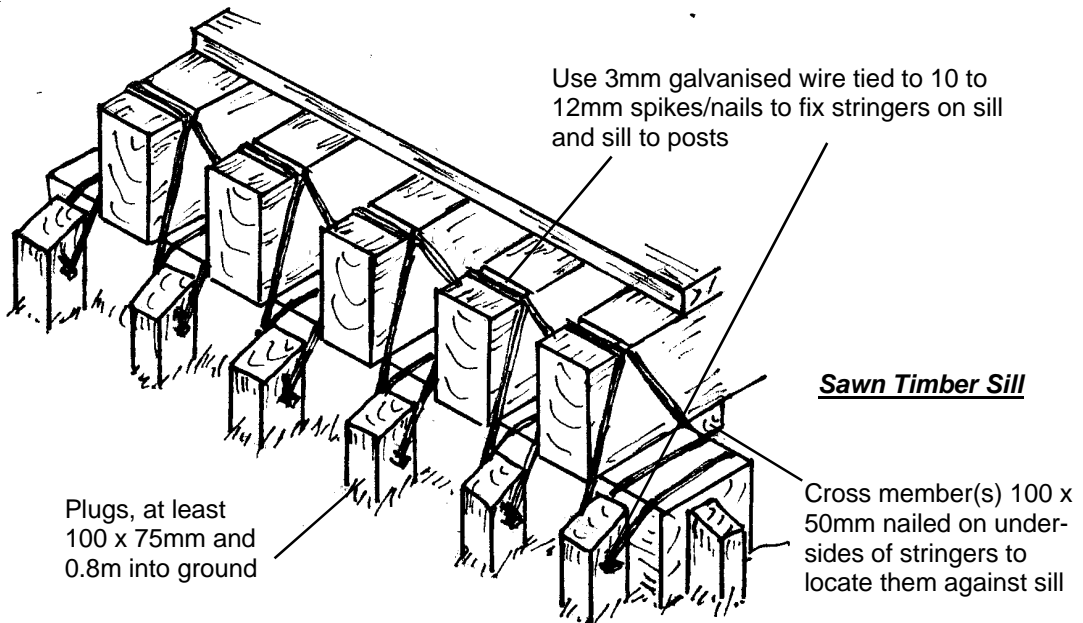


Figure 7.2: Timber Sill Abutments

7.2.4 Raised Timber Abutments

Often the level of the sill will need to be raised to match the level of the footbridge deck to the level of the path or track leading to and from the bridge, or to provide adequate clearance of the deck above flood waters.

Figure 7.3 shows two possible options for relatively flat banks where the sills have only to be raised a limited amount.

Option (i) is suitable where the soil is stable and reasonably firm. A flat base needs to be excavated. The stringers rest on a timber crib that is filled with stones/rocks and rubble to stabilise the abutment. Stability is further increased by sinking anchor posts at the four corners and binding the stringers to these with galvanised wire.

Option (ii) is suitable where the soil is less stable and the bank steeper. The sill log is supported on each side by piles sunk into the ground. The abutment is further stabilised by linking it to anchor posts sunk into the ground higher up the bank.

In both options the area up the bank from the abutment will probably need to be backfilled to build it up to the level of the path/track. This will need to be protected against flood-water, especially if the abutment is more than about 0.8m high. Large rocks and gabions (baskets filled with stones) may be used. Grass and plants with deep roots should be planted on exposed areas of soil.

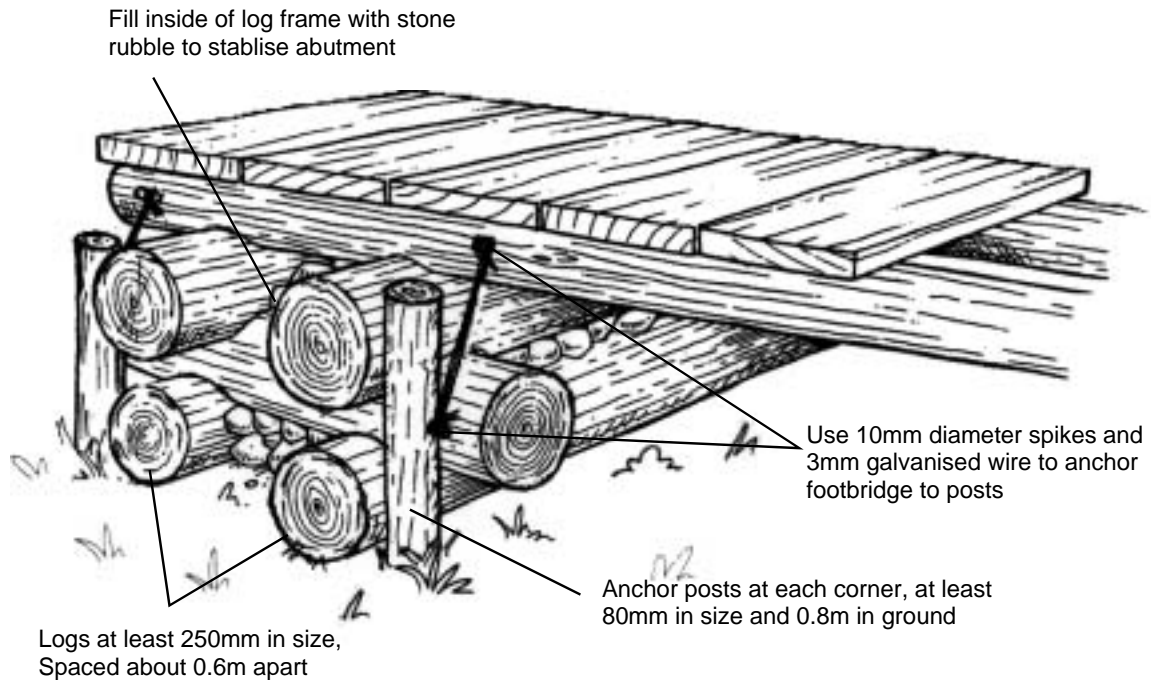
Wing-walls may be used for protection of back-fill for taller abutments.

Figure 7.4 shows examples of taller timber abutments with timber wing-walls for use on steeper banks. As well as protecting the back-fill, abutments and banks against erosion the wing-walls help the smooth flow of flood waters around the abutments. They can also be used to stabilise the abutment by linking it to anchor posts higher up the bank where the soil may be more stable. They are normally aligned at about 45° to the abutment.

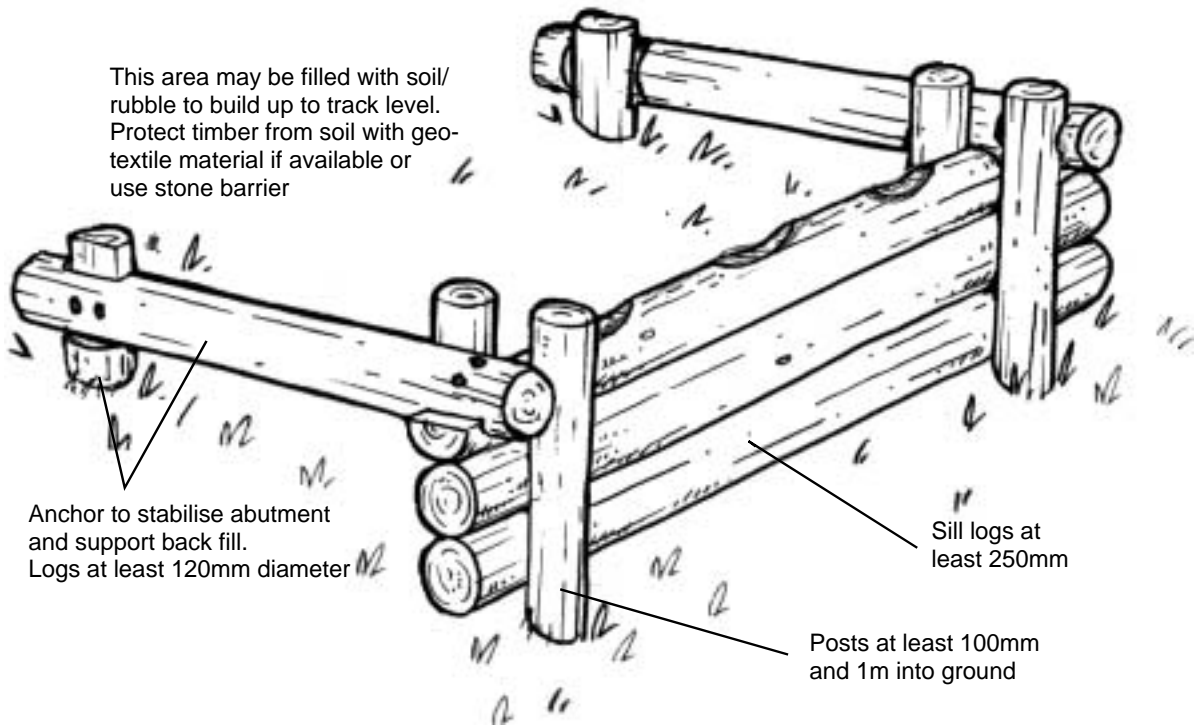
The back faces of abutments and wing-walls should be separated from back-fill with a barrier of stones to drain water away from the timber and protect it from moist soil that may cause rotting.. The other protective measures listed in Section 7.2.3 should also be used.

An example of a timber log bridge with log abutments and wing walls is shown in Figure 4.8 (Chapter 4).

Note: The maximum height recommended for the designs shown in Figure 7.4 is about 2m. Above this the design should be checked by a qualified engineer.

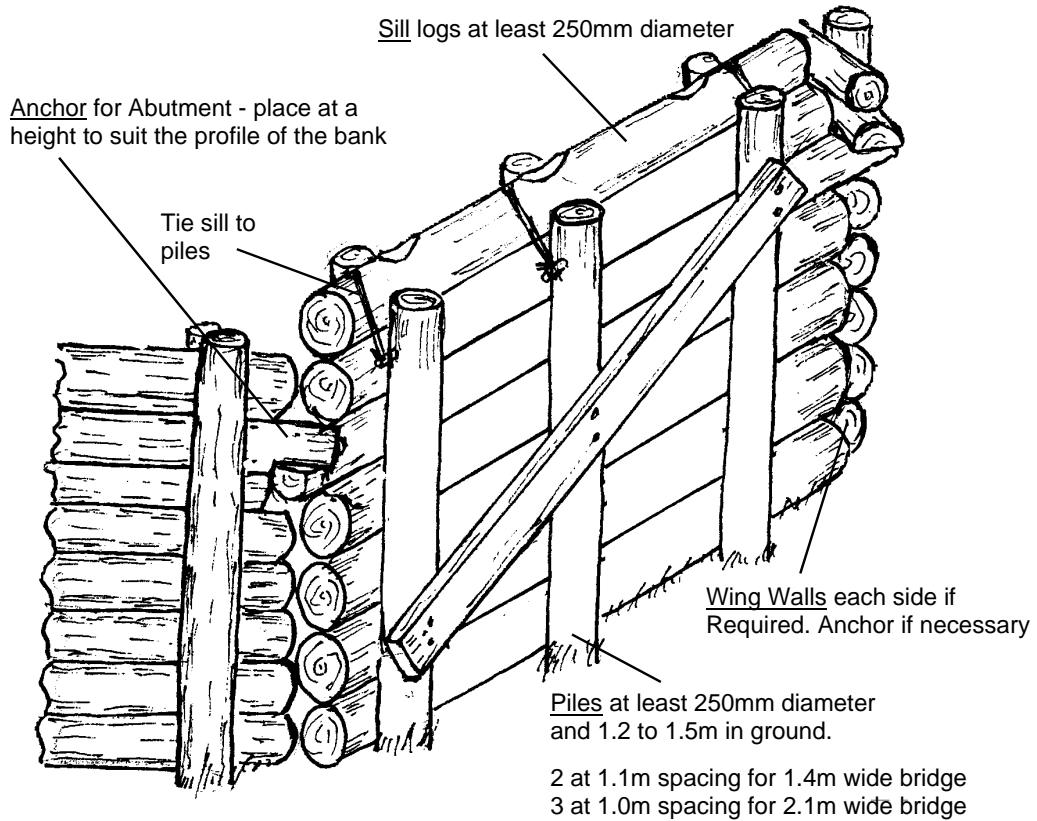


(i) Log Crib Abutment - suitable for fairly flat stable bank. If necessary excavate base for crib. Seat logs on a stone bed

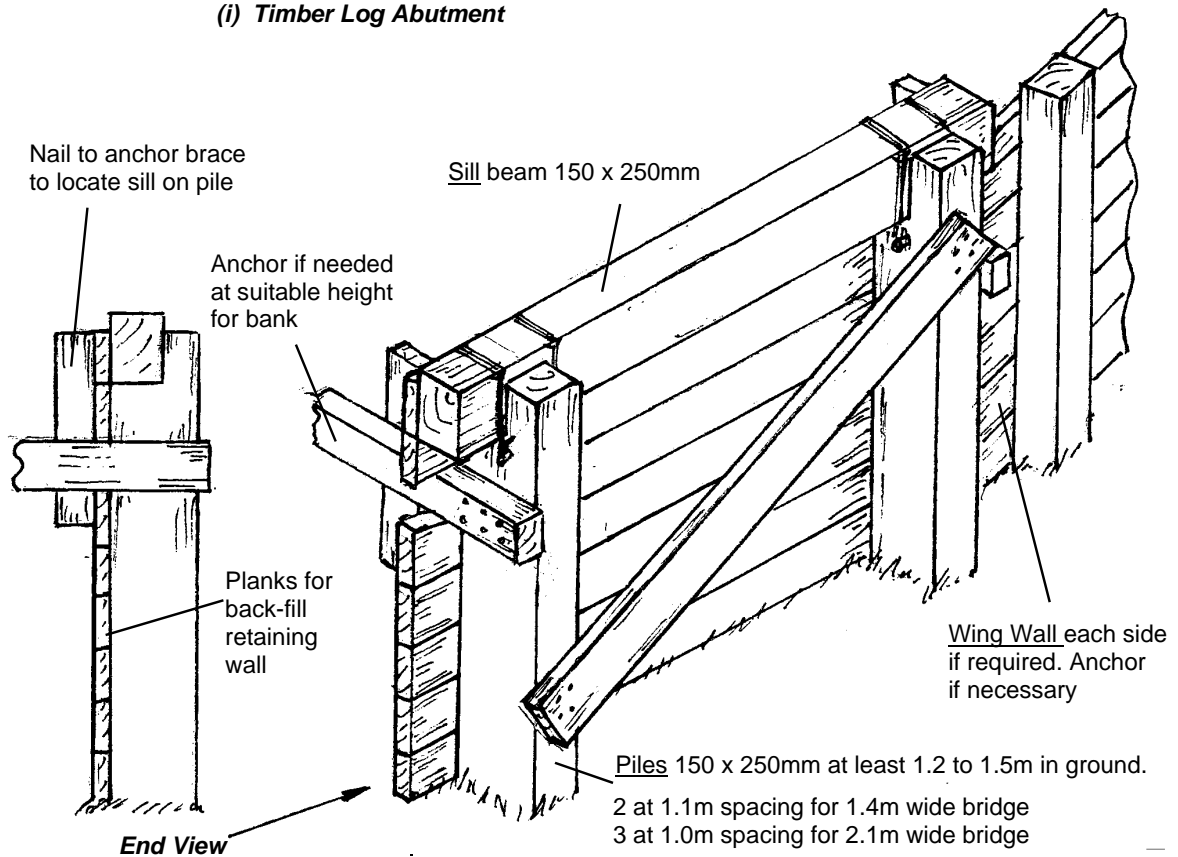


(ii) Log Abutment - suitable for medium slope bank

Figure 7.3: Log Sill Abutments for Low to Medium Slope Banks



(i) Timber Log Abutment



(ii) Sawn-Timber Abutment

Figure 7.4: Timber Abutments for Steep Banks or where Footbridge Deck has to be Substantially Raised

7.2.5 Concrete and Masonry Abutments

These will be considerably more durable and longer lasting than timber abutments but will also be more costly. They require the excavation of footings and the construction of formwork to produce the shape of the abutment. They will therefore need workers, including masons and carpenters, with some experience in this type of work.

Figure 7.5 shows an example of a mass concrete or masonry abutment with an integral wing-wall. If suitable stones are readily available the masonry construction will be cheaper than a concrete construction. The maximum height recommended for local construction of this type of abutment is about 3m (i.e. about 2.2m above ground). For stability, the base dimensions increase with the height.

The area of the footing must be compatible with the bearing strength of the soil where the abutment is to be located. A guide to the allowable bearing pressures for different soils is given in Table 7.1.

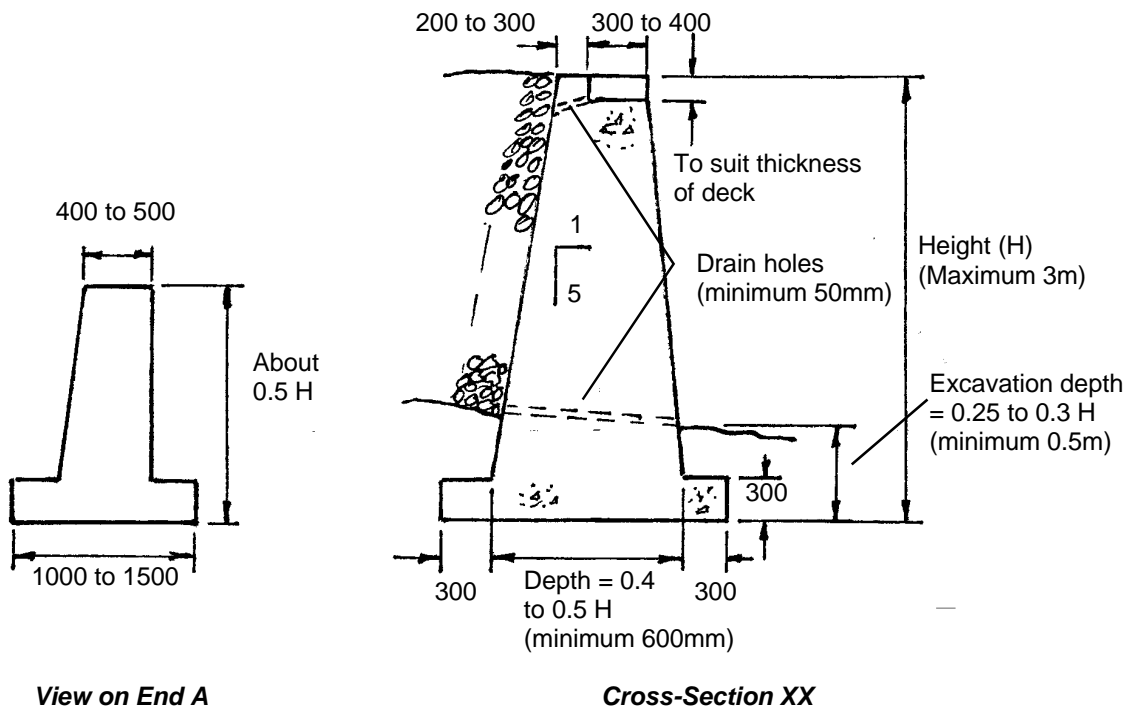
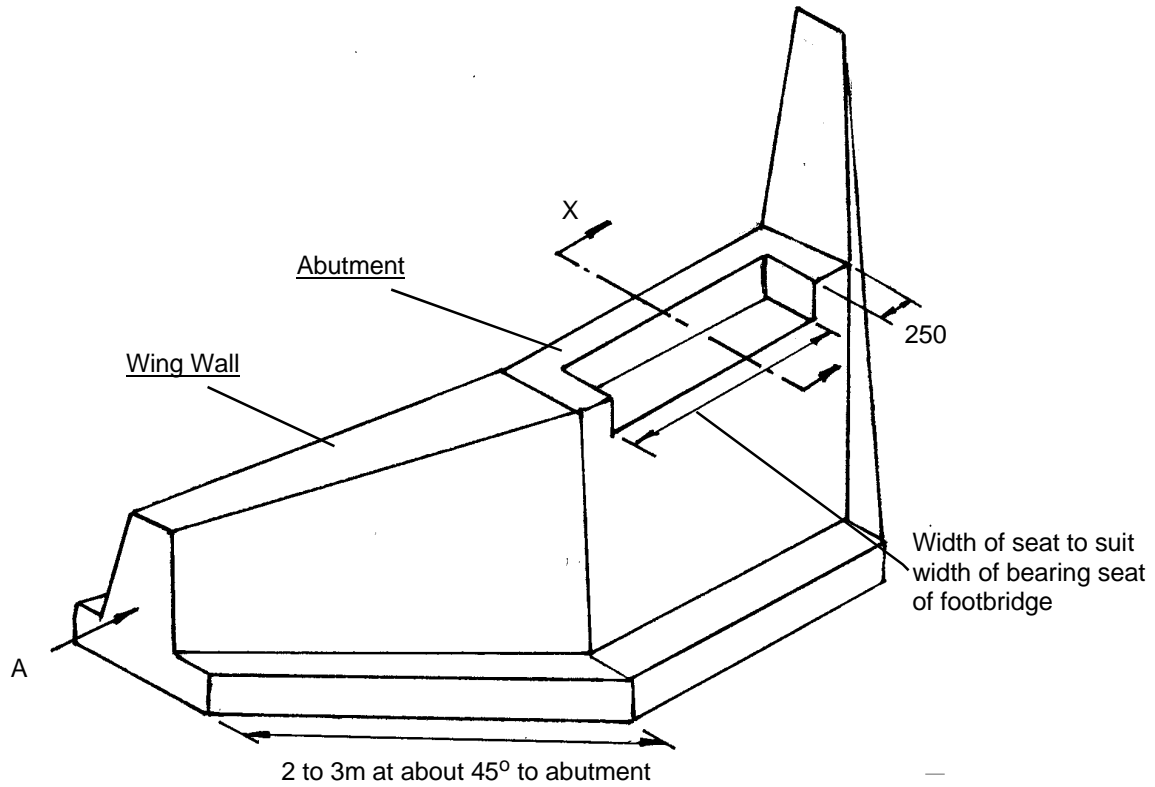
Table 7.1: Allowable Bearing Pressures for Various Soil Types

Nature of Soil	Allowable Bearing Pressure in KN/m ²
Rock	4,000
Dense sands and gravels	400
Medium dense sands and gravels	200
Loose sand and gravel	75
Firm clayey soil	100
Soft clayey soil	35

The maximum design load on the bearings for a 10m span x 1.4m wide footbridge is about 50KN/bearing. The minimum footing area for the abutment design in Figure 7.5 is about 2.4m². The footing area is therefore adequate for all soil types. However, it is advisable to avoid soft clayey soils where possible.

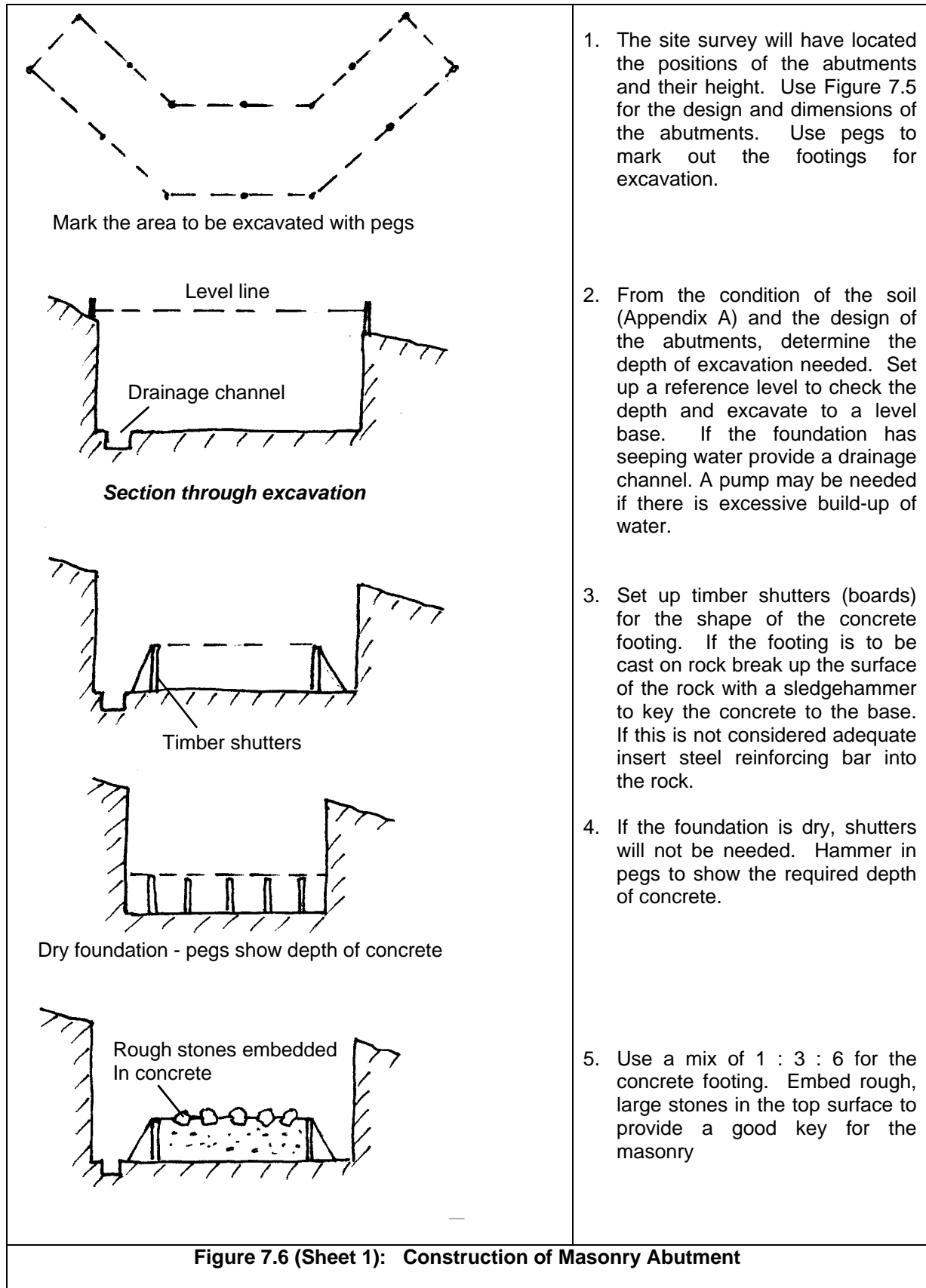
Construction of a Masonry Abutment

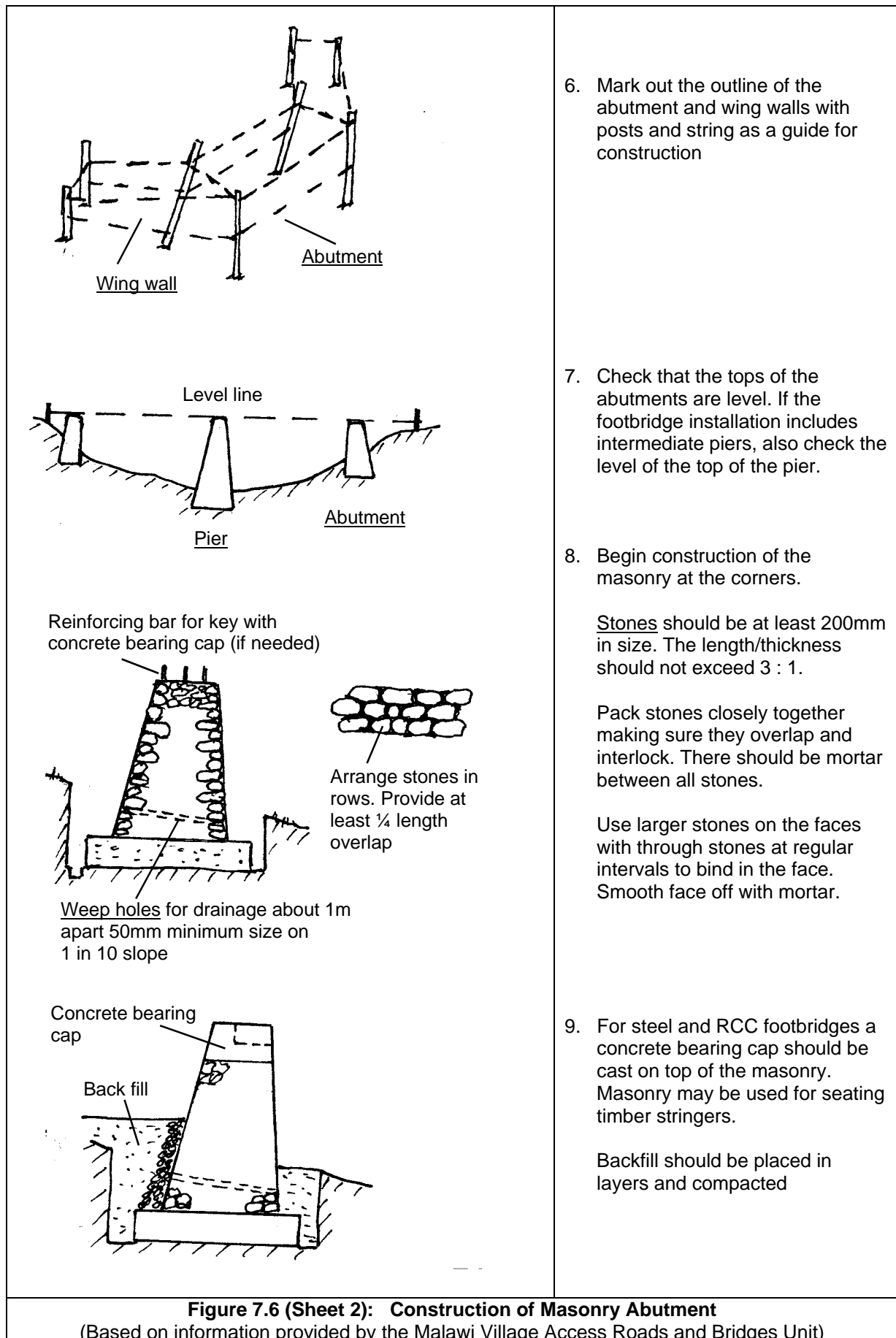
If suitable stones are locally available it is considered that a masonry abutment provides the best compromise between cost, long life and ease of construction. The steps in the construction of a masonry abutment are shown in Figure 7.6.



Materials: Mass concrete base 1 : 2 : 6 cement : sand : aggregate
 Masonry - well packed stones in 1 : 4 cement : sand mortar

Figure 7.5: Mass Concrete or Masonry Abutment





7.3 PIERS

Cases will often occur when the width of a crossing is greater than the maximum unsupported span for a footbridge superstructure. If the riverbed conditions are suitable it may be possible to increase the length of the footbridge by using intermediate pier supports. These are unlikely to be feasible in more hilly areas where banks are steep and where the bridge deck may be a considerable height above the stream/river bed.

Piers should be evenly spaced at intervals as close as possible to the maximum unsupported span of the type of footbridge being used. For example if the width of the crossing is 25m and the maximum unsupported span of the footbridge type is 10m, 2 piers will be needed at about 8.3m spacing.

As with abutments, piers may be constructed from timber, masonry, mass concrete or reinforced concrete. The same comments apply with regard to selection and construction.

Selection of type of construction:

- As with abutments, the long-term life of piers should be compatible with that of the footbridge. Therefore masonry or concrete piers should be used for steel and reinforced concrete bridges. Masonry is recommended where suitable stones are locally available.
- If suitable stones are locally available, masonry piers are also recommended for timber bridges as they are likely to give the lowest 'Total Life' cost. Timber piers, particularly using logs, will give a lower initial cost but limited life, maybe only 15 to 20 years. However, where there is all-year round flow of the stream/river that prevents excavation of footings for masonry or concrete piers, timber piers may be the only possible option.

Constraints:

Because piers have to be built in the stream/river bed there are more constraints on their construction outlined below:

- To excavate the footings for masonry or concrete piers, the riverbed needs to be dry in the dry season or to have limited water flow so that dams can be built to divert the water away from where the foot of the pier will be located. However, if this is not the case, it may be possible to sink timber piles in shallow water if the stream/river bed is suitable.
- The condition of the riverbed. For example, the use of timber piles may be difficult on stony or rocky beds. However, if rocks are suitable large and stable it may be possible to use them as a foundation for a masonry pier.
- The required height of the footbridge deck above the riverbed. The recommended maximum height for local construction is about 2 to 2.5m above the bed surface.

Piers obstruct the water flow and in the rainy season debris carried in flood-water may build up around the pier. If this is likely to be a significant problem the upstream end of the pier may need to be rounded to streamline the flow. Since the maximum water flow occurs at the centre of the stream/river it is best to locate piers away from this area if possible.

7.3.1 Timber Piers

Figure 7.7 shows piers constructed from timber logs and sawn timber beams. Piers support the joint between two bridge spans and therefore need to provide adequate bearing area for the ends of the two sets of joining stringers. In Figure 7.7 two cross-beams are used, each supporting one set of stringers.

The cross-beams must be securely fixed on the tops of the piles and also the stringers to the cross-beams.

The steps listed in Section 7.2.3 above should be taken to increase the durability of the piers. The length to be inserted in the ground should be soaked in a 50/50 mixture of creosote and diesel for a minimum of 2 weeks.

7.3.2 Installing Timber Piles

Constructing timber abutments and piers requires the sinking of timber piles into the ground. Up to about 0.8m this can be done by excavating a hole, installing the pile, back-filling and compacting the fill with hand rammers. For depths greater than 0.8m this becomes increasingly difficult and piles will need to be hammered into the ground.

Small diameter piles can be hammered in with a sledgehammer. Larger piles will need a larger impact. Figures 7.8 and 7.9 show two possibilities using concrete or hardwood blocks of about 100kg.

Figure 7.8 shows a fairly simple method in which the weight is lifted and dropped by 4 or more persons using timber poles attached to the block. The poles must be securely attached to the block but allowing rotation of the steel pin in the slot in the end of the timber pole. Different length poles may be needed for different heights of the pile above the ground.

Figure 7.9 shows a more complex method using a tripod, pulley and rope.

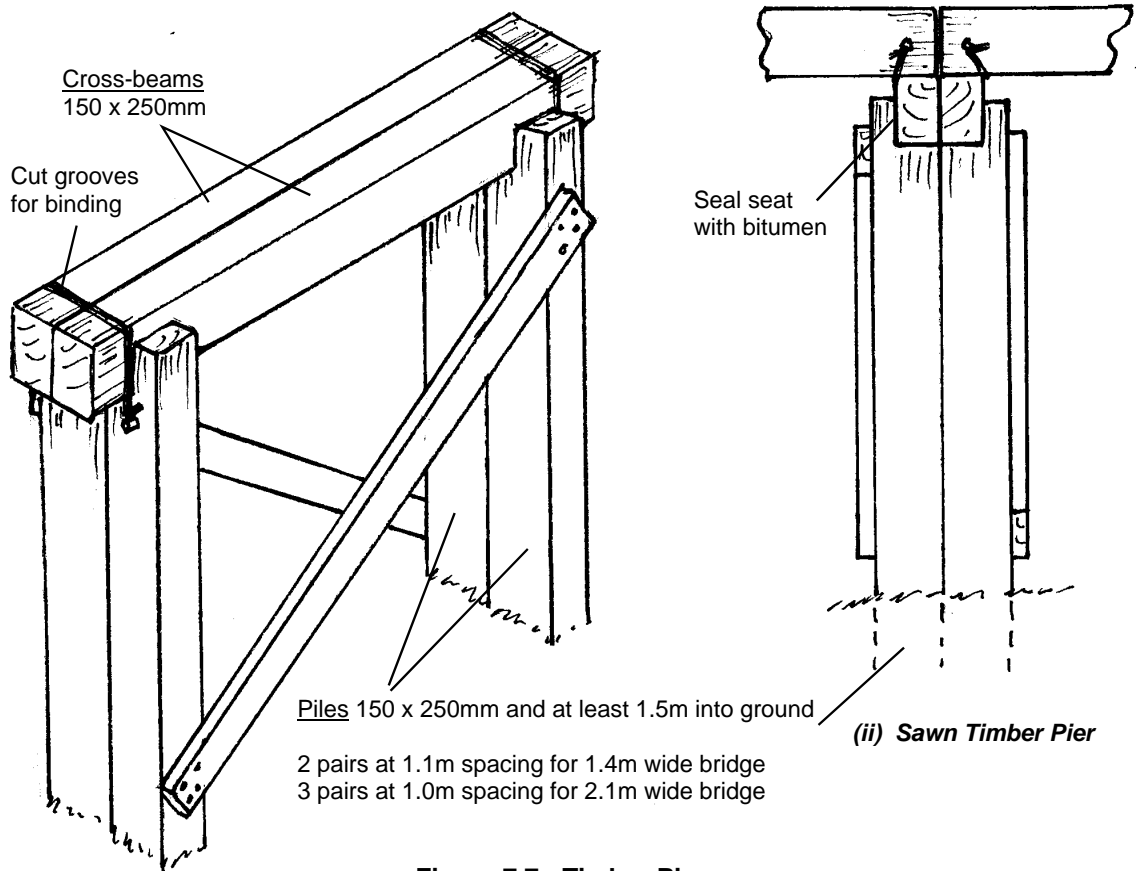
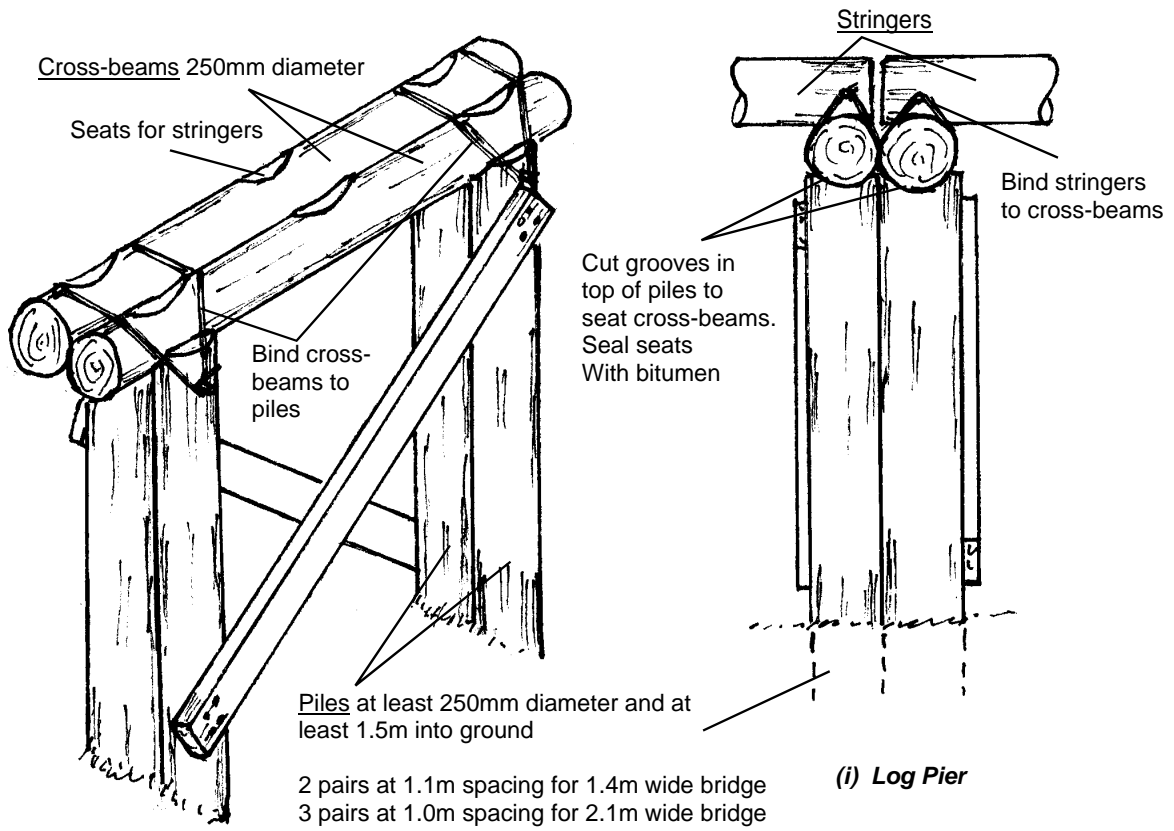
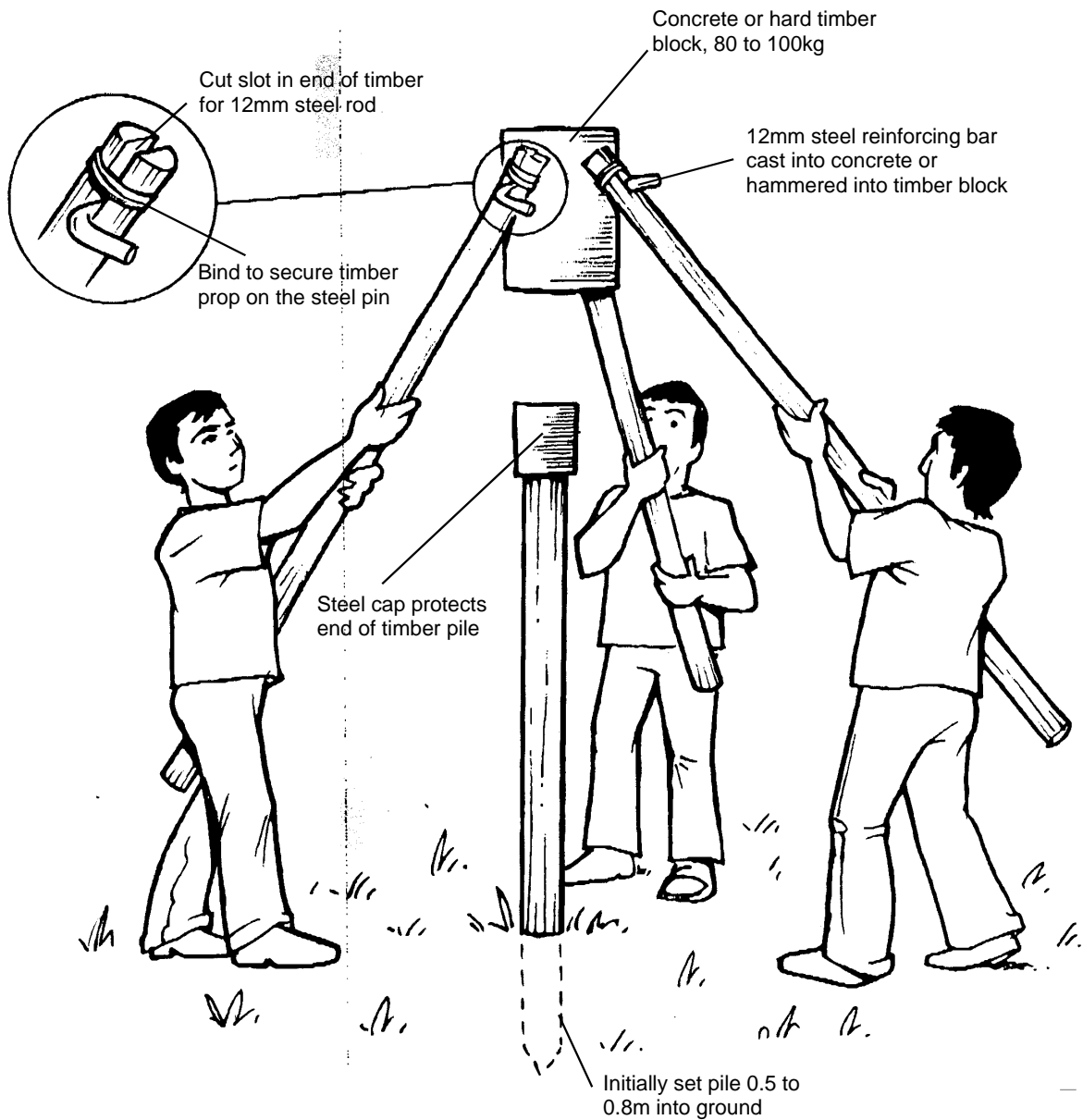


Figure 7.7: Timber Piers



Note: At least 4 persons (the nearest person has been omitted to show the details of the method) repeatedly lift the block 1 to 1.5m above the top of the pile and allow it to fall freely onto the steel cap.

Figure 7.8: Simple Method for Hammering Piles into Ground

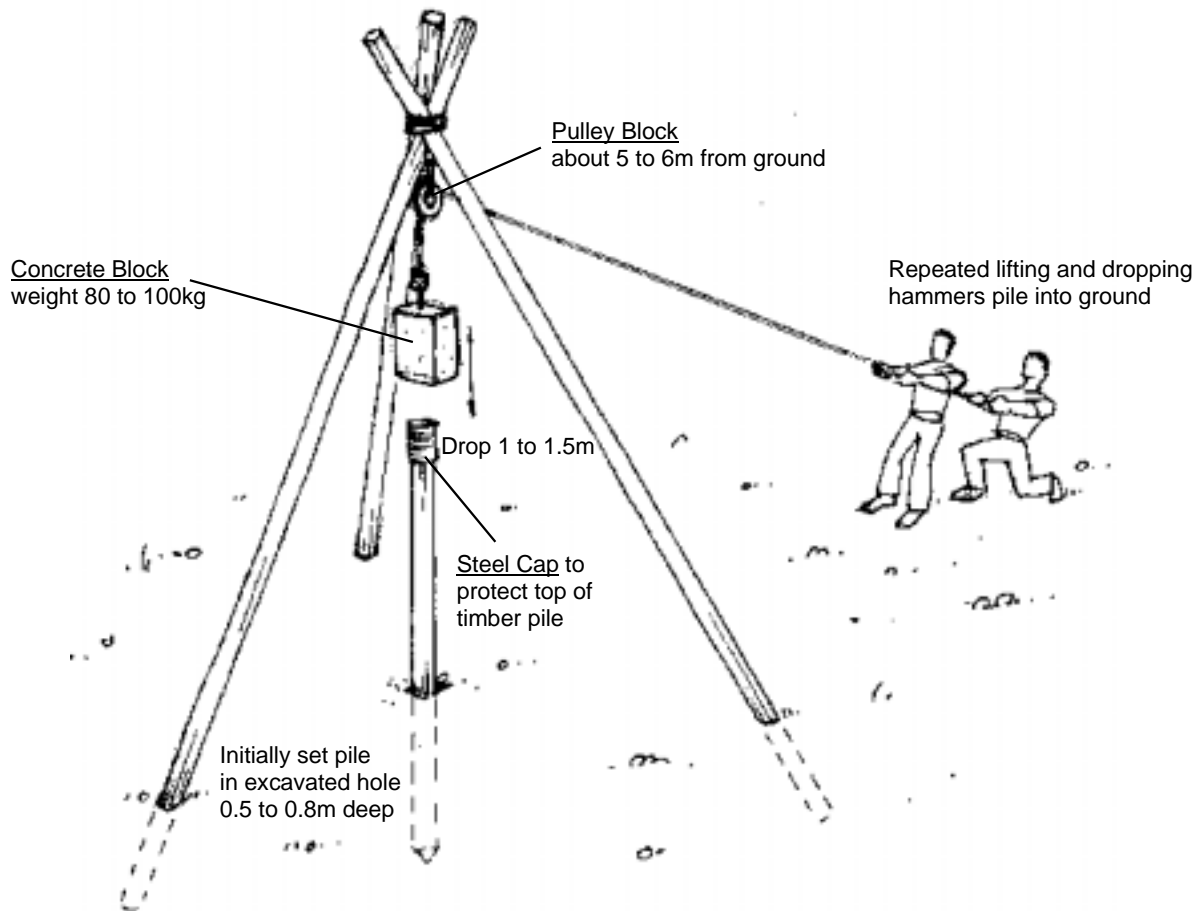
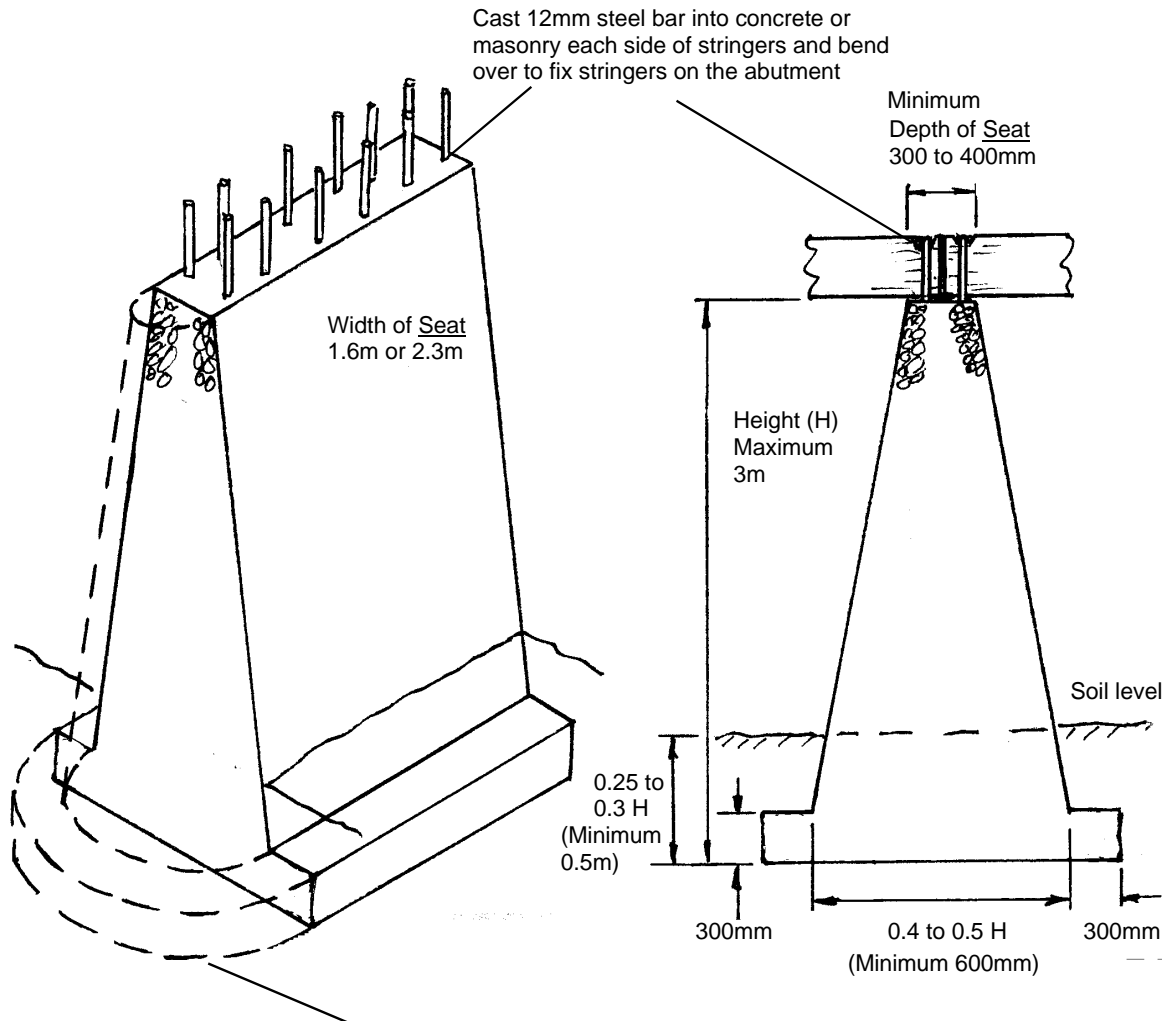


Figure 7.9: Sinking of Piles into Ground

7.3.3 Concrete and Masonry Piers

Figure 7.10 shows a suggested design for a concrete or masonry pier. Although more costly than timber piers these will require little or no maintenance and will have a much longer life. Their total life cost will therefore probably be lower than timber piers.

The pier needs to have a seat depth of 350 to 400mm to provide adequate bearing area for the two spans that join at the pier. It is recommended that hard rubber pads at least 10mm thick are used for the bearing surfaces. These should be about 5mm smaller all round than the bearing area to avoid trapping water on the seat. If suitable rubber is not available the seats should be sealed with bitumen.



If there is high water flow during the rainy season rounding the ends of the pier will help to reduce the disturbance to the flow

Materials: Mass concrete base 1 : 2 : 6
Masonry - well packed stones in 1 : 4 mortar

Notes:

1. The figure shows construction details for the support of timber beam stringers. Bearing seat details for steel and reinforced concrete footbridges are given in Chapters 5 and 6.
2. Construction procedures are similar to those given for masonry abutments in Figure 7.6.

Figure 7.10: Concrete or Masonry Pier

7.3.4 Bearing Arrangements

Although the footbridge spans must be fixed securely in position on the abutments and piers, care must be taken that the fixing arrangement does not set up forces in the bridge and support structures.

The main factor is to allow for expansion and contraction of the footbridge as temperatures change.

This is not a problem for timber bridges that do not change much in length with temperature so that both ends can be securely fixed.

However, the length of steel bridges changes significantly with temperature so that only one end of the span should be fixed. RCC can also change by a few mm in length so that only one end should be rigidly fixed.

Steel and RCC footbridges should therefore be fully clamped at one end but allowed to slide in the axial (lengthwise) direction at the other end while restrained in the side direction. A suggested arrangement for steel footbridges is shown in Figure 5.11 (chapter 5).

On piers where two spans of a steel or RCC footbridge join, the bearing of one span may be sliding while the bearing for the next span is fixed.

7.4 ERECTION OF FOOTBRIDGES

Although beam (stringer) types of footbridges can be built up on site, the individual beams may weigh up to 1200kg. They may also need to be lifted a considerable height above the river bed.

The total weight of a 20m span steel truss bridge (without the decking) will be about 2.5 tonne.

Simple methods that can be used by the local community under the guidance of a technical supervisor are therefore needed to erect heavy stringers or an assembled footbridge.

Three methods are shown in this section:

1. Using light beams to support the stringers
2. Construction of temporary scaffolding from the river-bed
3. The use of tripods and hoists.

7.4.1 Erection Using Light Logs (beams)

Figure 7.11 illustrates this simple method. 2 light logs, 120 to 150mm diameter are first dragged across the opening between the abutments. These will each weigh about 120 to 150kg so it will be possible for 2 to 3 persons to pull them into position (at least half the weight will be supported on the LH bank). The LH ends of the light logs are then strapped securely to the end of the stringer and the stringer pulled across the opening. As the end of the stringer passes half-way the light logs will begin to support some of its weight and this will increase as the stringer is pulled further. However, at the same time the bending arm on the logs gets smaller so that they will be strong enough to support the stringer. The stringer can be pulled and levered into position on the abutments.

Figure 7.12 shows an alternative method in which the two light logs are bound together and placed across the abutments at the largest possible angle to the centre line whilst remaining securely supported. The stringer is then pulled across the light logs.

7.4.2 Construction of Temporary Structure/Scaffolding Across Gap

Although this may involve considerable work it is possibly the most straightforward method. However, it depends on being able to build up the temporary structure from the river-bed and may not be suitable where the deck height above the bed is more than 3 to 4m. A suitable approach area is also needed to the abutment on the near bank over which the stringer or bridge can be dragged on rollers.

Figure 7.13 shows the basic method. The structure must be securely lashed together and well braced against the forces used to pull the stringers/bridge into position. The stringer/bridge may be pulled into position by hand if enough labour and space is available but using a winch will be easier and give more control over the operation.

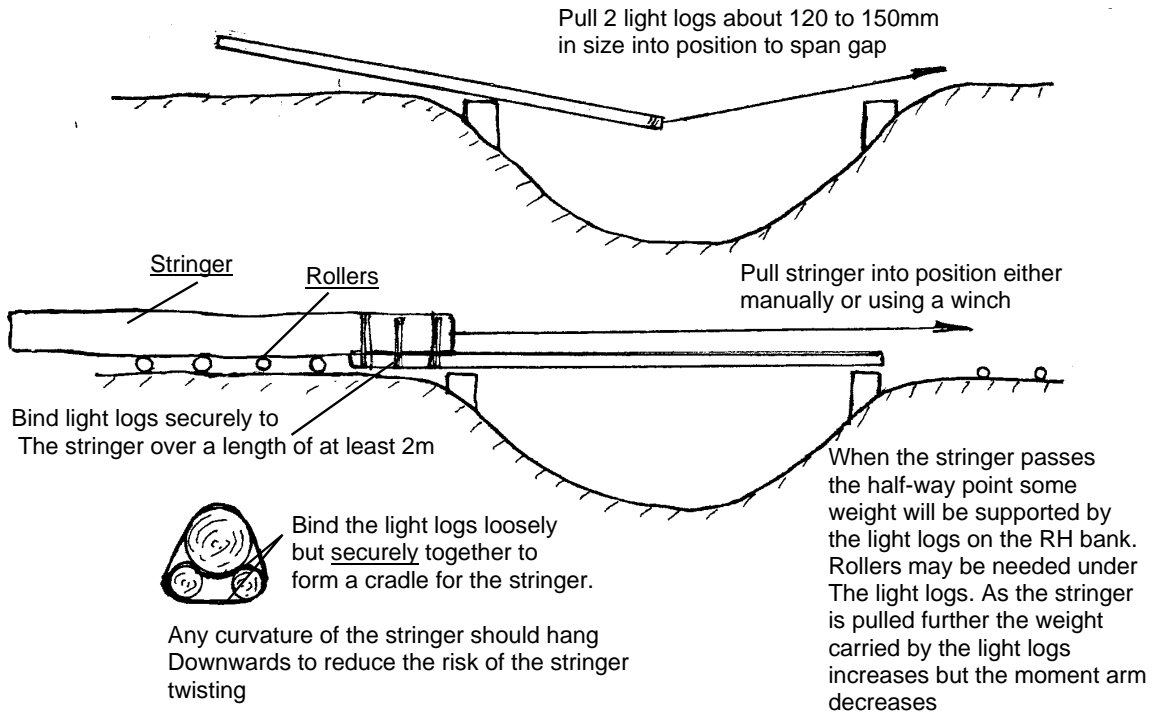


Figure 7.11: Installation Using Light Logs to Support Stringers

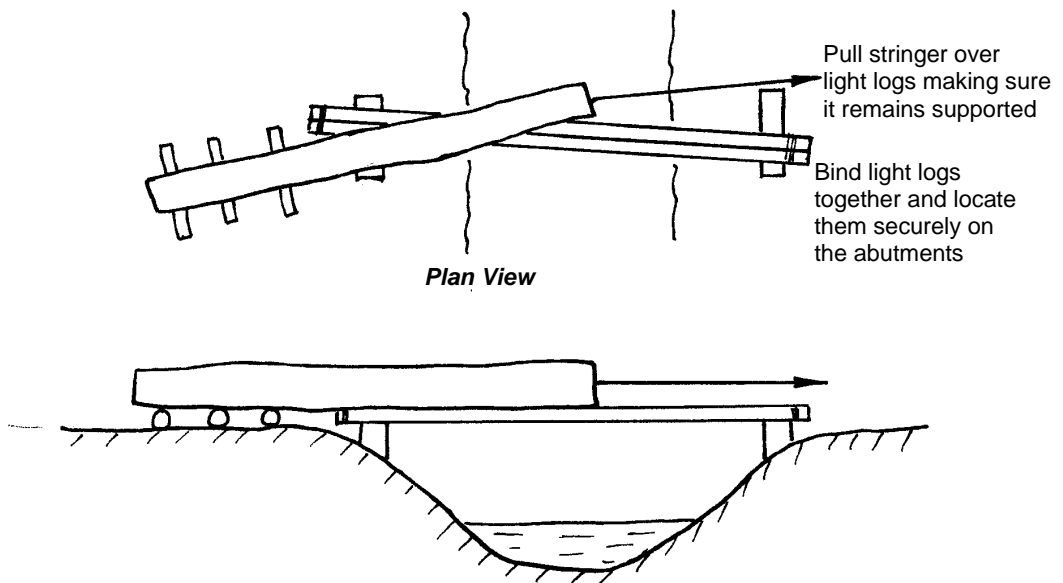


Figure 7.12: Use of Light Logs to Support Stringer
(Method suggested by VARBU, Malawi)

7.4.3 Use of Cable Way to Lift Stringers/Bridge into Position

This is probably the most difficult and costly option but it may be the only one possible in some situations, especially for wider crossings. It will require the acquisition, possibly by hiring, of hoists or winches, cables and ropes and pulley blocks. It will also need careful technical supervision from a person with experience in this type of operation.

Figure 7.14 shows the simplest method. Towers or tripods are mounted on each bank to support a cable on which a pulley block travels, supporting the stringer being installed. The legs on the river side must be securely fixed in the ground and the structures well braced with guy ropes to prevent them tipping towards the river. Ropes are used on each side to control the pulling of the stringer into position.

Care must be taken to pull the stringer evenly.

A winch should be used for pulling if possible. If not the pulling rope should be wrapped around an anchor post to prevent the traveller running backwards. A lifting device such as a chain hoist is needed on the traveller to lower the end of the stringer onto the abutment.

The sag in the cable should be about 10% of the distance between the 2 tripods. This will give a maximum tension in the cable of about 1.3 x the weight being moved (assuming half the weight is supported on the nearside bank).

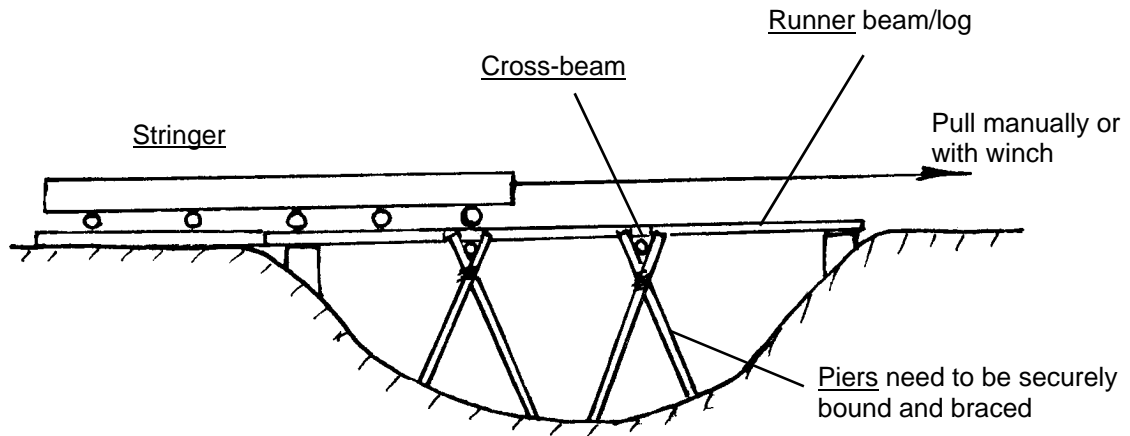
Allowable loads in cables (assuming they are sound and not frayed) are 1.0 tonne for a 6mm cable and 2.5 tonne for a 10mm cable.

Safe working loads in ropes are:

- Manila (fibre) ropes – 1 tonne for 25mm; 2 tonne for 32mm; 2.5 tonne for 36mm
- Blue polypropylene ropes – 1.4 tonne for 10mm; 2 tonne for 12mm; 3.5 tonne for 16mm

The method is particularly suitable for the installation of modular truss footbridges where the bridge can be built up close to the tripod on the nearside bank as it is lifted and pulled over the crossing.

An example of this is shown in Figure 7.15. In this case the cables and guy ropes have been anchored to trees on each side of the river because the soil (paddy fields) was not suited to putting anchor posts in the ground. Note that a platform has been erected on the near side of the river on which the footbridge is assembled module by module.



Erect temporary piers with cross beams to support runners (logs/beams) on which stringer can be pulled across gap

Figure 7.13: Installation Using Temporary Piers

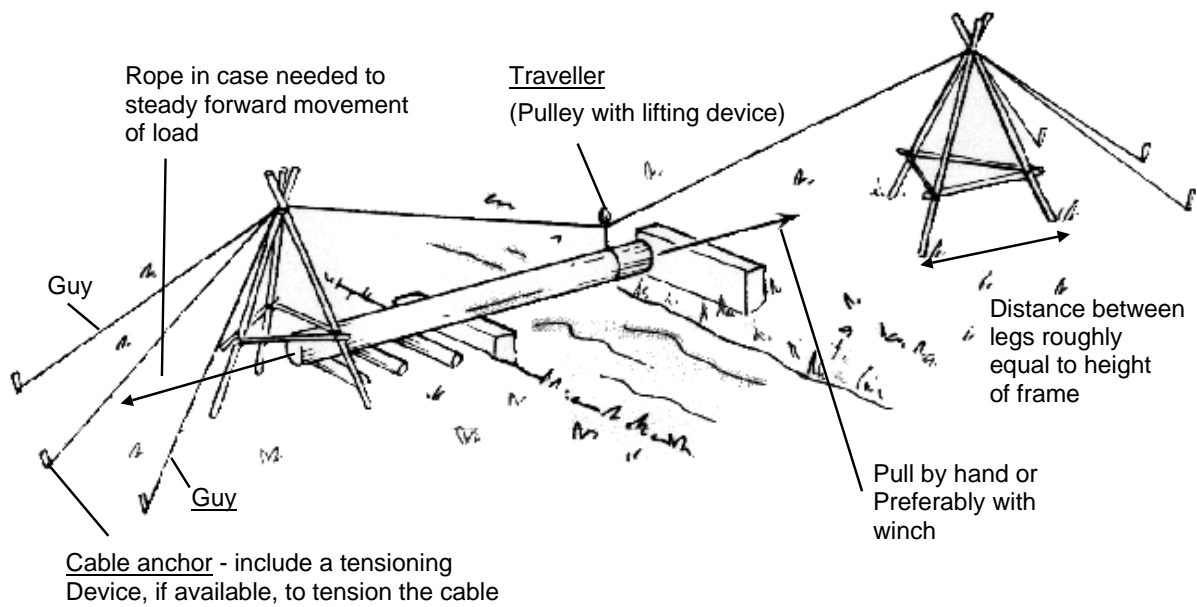


Figure 7.14: Installation Using Hoists



Figure 7.15: Use of Cable Trolley to Install a Modular Steel Truss Footbridge

7.5 ORGANISATION OF WORK

The work programme can be split into three main components –

(1) Planning and preparation; (2) Implementation; (3) Ongoing maintenance.

7.5.1 Planning and Preparation

In most cases, footbridges will be installed along paths or tracks for which the local community is responsible. The request for a footbridge is likely to have come from the community. It is therefore important to liaise closely with the local communities at all stages of the work programme and especially during the planning and preparation stage. Decisions, costs and inputs should be agreed with the communities.

It is very important to emphasise to the community that the installation of a footbridge is a major undertaking and will require a great deal of commitment from the community in labour and possible other resources. It is likely to overshadow any other community projects and there will need to be a consensus from the community that a footbridge is by far their number one priority.

Guidelines on working with communities and providing technical assistance are discussed in detail in a previous publication on footpaths (see footnote on Page 1). Important issues are to keep the communities informed, to get agreement on decisions regarding the footbridge and to draw up contracts on expected community inputs in regard to funds, materials, labour and ongoing maintenance.

The main activities in the planning and preparation stage are outlined below.

1. **Site survey:** (see Appendix A). This should provide a plan of the site and give the specifications of span and width for the footbridge. The plan should show the topography of the banks and river-bed at the proposed crossing and give details of surface and soil conditions. The possibility of using intermediate pier supports if needed should be clearly identified. The location of abutments and piers (if used) should be shown.
2. **Selection of type of footbridge:** this is discussed in Chapter 3. The main factors to be considered are – span; if piers can be used where the span exceeds about 8 to 10m (4m for bamboo bridges); the availability of materials; skills needed; and both initial and long-term (total life) cost.
3. **Design of footbridge:** this will probably be based on a standard design from Chapters 4, 5 or 6 or some other source of information. A sketch should be prepared showing all dimensions, details and materials. From this a materials and cost list should be drawn up as indicated in Table 7.1 below.

Table 7.1: Materials and Costs List

Item	Material	Section and Size	Length or Volume	Number Needed	Source of Supply	Unit Cost	Total Cost

Table 7.1 will give an estimate of the material cost of the footbridge. Costs of consumable items such as paint and preservatives should also be estimated. If the construction of the footbridge is carried out in a workshop, such as with a steel truss footbridge, then appropriate workshops should be provided with the design sketches and asked to quote a price for construction.

The labour inputs and costs then need to be estimated by identifying the steps in the construction process and the inputs required for each step. Some guidance can be obtained from Chapters 4, 5 and 6, Appendix B, previous experience and discussions with relevant craftsmen. Inputs can be listed in a table such as Table 7.2.

Table 7.2: Estimate of Labour Inputs and Costs

Item	Activity or Operation	Tools needed	Type of Skills needed	Estimate of work days needed	
				Skilled	Unskilled

Adding up the work-days in Table 7.2 gives the total work-days needed for each skill (type of craftsman) and for unskilled workers. This in turn gives an estimate of the inputs needed from the community and any inputs that have to be imported. The labour cost for constructing and erecting the footbridge can then be found by multiplying work-days that have to be paid for (community inputs may be unpaid) by average unit rates in the area.

All activities involved in the construction and erection of the bridge (not abutments and piers which are considered separately below) should be included in Table 7.2, including:

- Collection of materials
- Transport of materials and components to site
- Handling of materials and components on site
- Construction and assembly processes
- Preparations for erecting the footbridge as indicated in Section 7.4 above, for example preparing surfaces for rolling stringers or footbridge, setting up lifting gear etc.
- Erection of the footbridge
- Backfilling to link the footbridge to approach paths/tracks.

4. Design of Abutments and Piers: a similar procedure should be followed as for the footbridge. Tables similar to 7.1 and 7.2 can be used. Erection may involve clearing of the site, excavation of foundations and sinking of piles. Standard unit rates for the first two are:

- Clearing – 50m² per work-day for heavy vegetation to 150m² per work-day for light vegetation
- Excavation – 3 to 5m³ per work-day (does not include the movement of excavated soil)

Times for sinking of piles can be estimated from experience for the size of pile, depth into ground, nature of soil and method used.

5. Identify total inputs and resources needed and potential sources of supply: the above steps will provide an estimate of the total inputs needed comprising labour, materials, costs of materials, tools and equipment. These need to be split into two components:

1. What can be provided by the local communities that will benefit from the footbridge. This will need to be discussed in detail with communities and an agreement drawn up and signed by the communities to confirm their commitment
2. What needs to be obtained from outside the communities. This will be mainly a total cost which cannot be met by the communities for materials, skilled labour that has to be imported and tools/equipment that have to be hired or purchased.

If outside assistance is needed a proposal will need to be prepared justifying the funds requested against the benefits of the footbridge. This will require an assessment of the access improvements provided by the footbridge and the number of people who will benefit. Improvements in access may include:

- Providing access to services where no access exists at present. This is likely to relate to access in the rainy season. Providing access to health, education and market facilities is especially important
- Saving time in access to services. Again saving time in access to health, education and market facilities is especially important
- increasing the amount of produce transported to markets to increase household incomes. Careful assessment is required to obtain realistic estimates based on discussions with the communities and local traders to assess potential for increased household production, potential for increased market sales and the possible impact of increased market inputs on prices.

The proposal should be realistically prepared and submitted to potential funders.

7.5.2 Implementation

The planning stage will have identified all activities involved in installing the footbridge and the estimated work-days needed for each activity. Based on the work force available the days required for each activity can be estimated. This information should be put into an implementation chart or table similar to that shown in Table 7.3. This will show the activities, the sequence in which they need to be carried out and when they should be completed. A copy of the chart should be put up in a prominent place in the communities involved and kept up to date to show progress.

Table 7.3: Implementation Chart

Activity	Person or Group responsible	Period over which the Activity is to be carried out. X shows the scheduled completion date. Include notes to explain any delays					
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
1. Clear site	Community A	X					
2. Mark out abutments	Supervisor		X				
3. Acquire and prepare suitable logs	Community B				X		

All activities should be included and the total weeks scheduled for installing the footbridge.

7.5.3 Maintenance

Ongoing maintenance to a regular schedule is very important to prolong the life of the footbridge and to achieve good value from the time, effort and funds invested in installing the footbridge.

A Maintenance Schedule should be drawn up showing activities required, when they are to be carried out and who is responsible for them. This should be discussed and agreed with the responsible communities who should sign a contract agreeing to carry out the work.

Guidelines on the maintenance needed for timber footbridges is given in Section 4.5 and for steel truss footbridges in Sections 5.2.11 and 5.3.3

APPENDIX A

SITE SURVEY AND LAYOUT OF BRIDGE

The factors to be considered in locating the bridge are listed in Section 2.1.1. Once the location has been selected the site needs to be surveyed to establish the specifications for the bridge and its abutments. The survey needs to determine two main factors:

1. The location of the abutments and the span of the bridge based on: (i) the Design Flood Level and clearance needed below the bridge to allow for debris carried in flood waters; (ii) clearance needed for any boats using the stream/river during non-flood conditions; (iii) the slope and soil conditions on the banks
2. The width of the bridge based on the types and levels of traffic that will use the bridge.

Location of Abutments

The survey procedure is shown in Figure A1 and involves the following steps:

Step 1 Identify and mark with pegs the Design Flood Level based on inspection of the banks and discussions with local persons.

For medium traffic levels (less than 500/day) and normal access needs the DFL could be the maximum flood level reached on average every 5 years

For high traffic levels (over 500/day) and/or critical access needs the DFL could be the maximum level reached on average every 10 years

Step 2 Place marker poles on each bank along centre-line of bridge location.

Step 3 Obtain information on debris carried in flood-waters and decide on clearance needed above the DFL. Mark this clearance on the marker pole on one bank.

Step 4 Obtain information on any boats or canoes that use the river/stream and the normal level of water on which they operate. Estimate the clearance needed for these boats and mark this height on the marker pole.

Step 5 The top level of Steps 3 and 4 will set the initial height and location of the abutments. Use a clinometer or line level to give a horizontal reference line to locate the abutment on the other bank at the correct height.

Step 6 It is now necessary to check that the initial locations on the two banks are suitable for the abutments. The soil condition should be stable and as firm as possible. Based on the stability of the soil a slope line should be established for each bank to indicate a safe region for location of the abutments.

Step 7 Establish the profile up and down each bank to at least 3m above and 4m below the abutment location by taking height measurements at 1m intervals from a horizontal level line. Plot these on a sheet of paper.

Step 8 Draw a line from the bottom of the profile at an angle to suit the soil condition. Recommended angles from the horizontal (see Figure 2.2) are as follows:

- for stable rock angle can be up to 60°
- for firm, stable soil the angle should not exceed 45°
- for soft soil and sand the angle should not exceed 35°

If the locations of the abutments lie OUTSIDE this line (Case A) they should be satisfactory. If INSIDE this line (Case B) it is necessary to relocate the abutment outside the line. Careful consideration needs to be given to this as increasing the span of the bridge will increase cost. On the other hand it is imperative that the bank and footings do not slip or collapse due to the weight on the abutments.

Step 9 The suitability of the soil for abutment foundations at the proposed location can be checked with a cone penetrometer. The procedure for this is outlined in Figure A.2.

Step 10 Once the locations of the abutments have been finalised measure the profile along the bank for 3m each side of the centre line of the bridge. This should be reasonably level to minimise excavation of the footings for the abutments.

Step 11 Record the conditions and decisions taken in Table A1.

Traffic that will use the Bridge

The type of traffic that will use the bridge determines the maximum *width* of the bridge needed to provide access for regular users of the bridge. If the type setting the width of the bridge uses the bridge less than 1 or 2 times per month then careful consideration needs to be given as to whether it is worthwhile to increase the width and cost of the bridge to accommodate this low-frequency user. This has to be judged in terms of the need for access and the availability of other access routes.

The type and level of traffic, particularly the amount on the bridge at any one time, determines the loading that the bridge has to carry.

The data on users of the bridge should be obtained from traffic surveys and discussions with local communities and recorded in Table A1. The user setting the width of the bridge should be clearly identified.

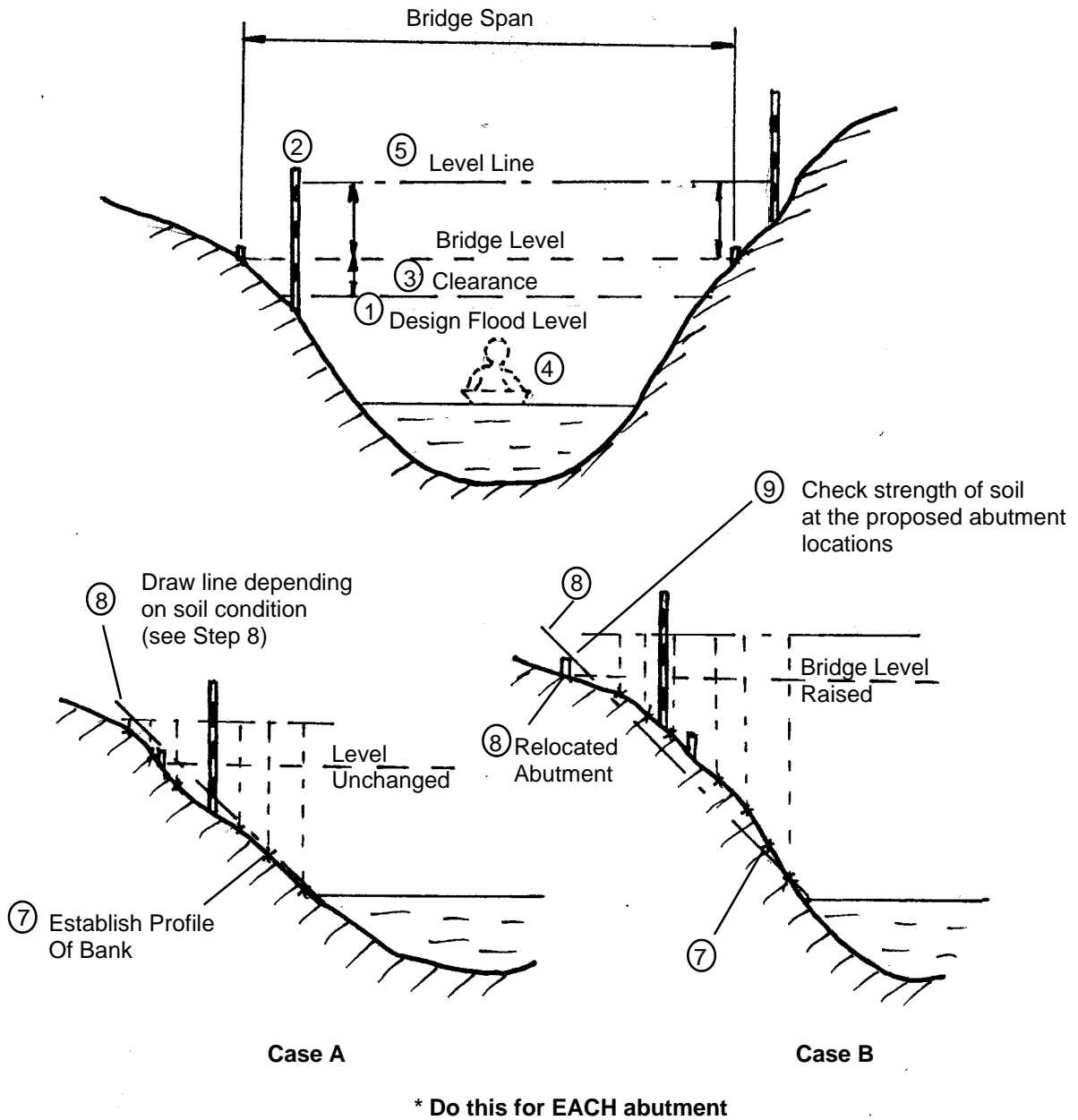
Plan of Area of Abutments

If necessary, make a sketch with explanatory notes of the areas where the abutments are to be located and show any obstructions which will need to be moved and any signs of erosion that could affect the footings of the abutments.

Option of Using Piers

If the span is found to be greater than about 8m then the option of using piers should be considered to allow the use of timber stringer type bridge structures (timber logs or sawn timber beams) or to reduce the strength and size needed of truss type structures. Piers may be located at about 8 to 10m centres depending on the lengths of logs or beams that are available.

If the use of piers is a possibility, additional information will be needed from the site survey as indicated below.



Note:
The numbers in the circles refer to the Step Numbers in 'Location of Abutments'.

Figure A1: Site Survey and Location of Abutments

What is the average depth of water during the dry season?m

1. What is the average width of the stream/river during the dry season?m

2. Describe the condition of the stream/river bed at locations where piers might be located. This need to be considered particularly in regard to the types of footings that may be used for the piers (see 4). Make a sketch showing important features.

.....
.....

3. Which type of footing would be most appropriate for the piers?

(i) A crib (a timber or steel structure that rests on the surface and is weighed down by rocks)

(ii) Timber or steel piles driven into the bed

(iii) Masonry or concrete piers constructed on rocks in the river/stream bed

(iv) Masonry or concrete piers with excavated footings

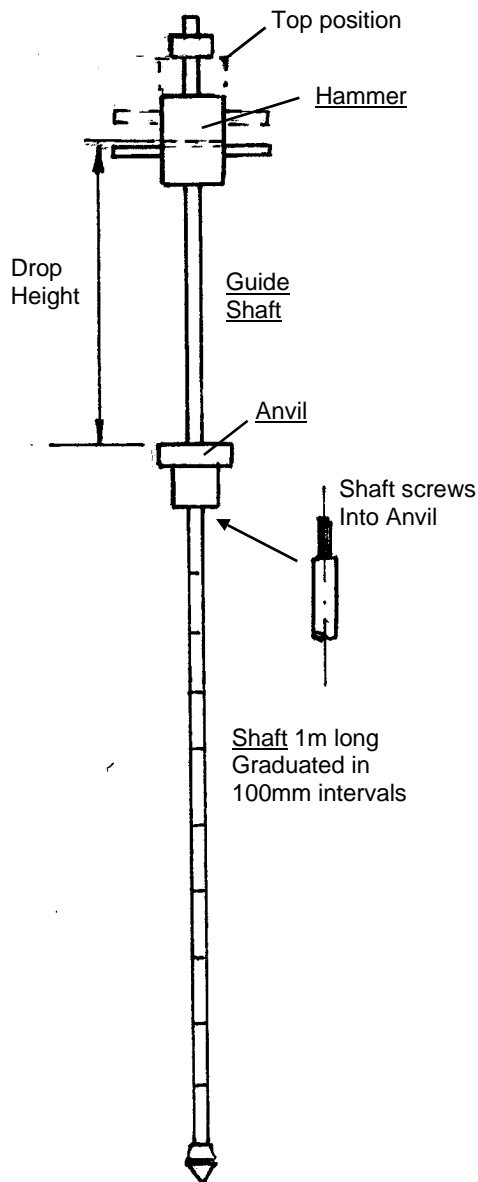
4. Use a level line or the water surface as reference to measure the depth of the stream/river bed at 1m intervals in order obtain the profile of the bed. Measure the vertical height of the level from the level of the abutments as indicated in Figure A1.

Table A1: Record of Conditions and Decisions

Factor Considered	Condition or Decision				
Design Flood level	Frequency of flood considered: Average yearly				
	1 in 5 years				
	1 in 10 Years				
	How accurate/reliable is this? Good; Medium; Poor				
Use of river/stream by boats	If river/stream is used by boats, how often?				
	Average number/day in dry season				
	Average number/day in wet season				
Level of bridge	What was factor that set level of bridge?				
	(i) Design Flood Level				
	(ii) Clearance for boats				
	If (i) what clearance is provided above DFL				
	If (ii) what clearance is provided for boats				
Soil condition at location of abutments	Tick which of the following best classifies the condition of the soil at the abutments:				
	1	Stable rock formation			
	2	Shale and soft sandstone			
	3.	Soft limestone			
		Dense sands and gravels			
		Hard clayey soils			
	4	Medium dense sands and clayey soils			
	5	Loose sands, gravels and soft soils			
Relocation of abutments	Have the abutments been relocated because of the slope of the bank or soil conditions? No ; Yes				
Span of bridge	1 Span of bridge for initial location of abutmentsm				
	2 Bridge span after relocation of abutmentsm				
Traffic that will use the bridge (4) - Type	Average number/day	Maximum number/day	Maximum likely on bridge at one time	Typical (1) maximum weight (kg)	Typical (1) maximum load carried (kg)
Pedestrians					
Bicycles					
Livestock - Donkeys					
Cows/oxen					
Buffalo					
Pack animals (2)					
Motorcycles					
Wheelbarrows					
Handcarts					
ADVs – Animal (3)					
Cart					
Car/pick-up					

- Notes:**
1. Less than 5% would exceed this
 2. State type
 3. State type, number and maximum weight PER ANIMAL
 4. Which of these determines the width needed for the bridge?
.....
What is the access width needed? m.
How often would this type use the bridge? Times/month

Bridge specifications: **Span m**
 Width m



Using a Cone Penetrometer to Test the Strength of the Soil

- a. With the cone resting on the ground and the instrument held in a vertical position, raise the Hammer to its top position and allow it to fall freely onto the Anvil.
- b. Repeat this process and record the number of blows for the cone to be driven 100mm into the soil.
- c. Continue the process and record the number of blows for each 100mm of penetration.
- d. If at 1m of penetration a sound foundation base has still not been reached (see guide below), unscrew the anvil from the shaft and insert a 1m extension of the shaft.
- e. Continue the above process until a sound base is reached. However, because of the problems of excavation in soft soils, careful consideration should be given to relocation of the abutments if a suitable stable base has not been reached by about 1.2m depth.

Guidelines on suitability of soils for abutments and piers

(Based on notes by the VARBU in Malawi)

- Below 15 blows per 100mm penetration – soil not suitable
- 15-20 blows per 100mm – not suitable for shallow foundations
- Over 20 blows per 100mm – generally suitable

Figure A.2: Checking the Soil Strength for Location of Abutments and Piers

APPENDIX B

CONSTRUCTION OF MODULAR STEEL TRUSS FOOTBRIDGE

B1 INTRODUCTION

Chapter 5 contains the design details of a steel truss footbridge for spans of 10 to 20m. Two standard widths are included, 1.4m and 2.1m. However, the design can readily be adapted to other widths by changing the width of the base panels.

The design is made up of modules formed by bolting together 2 side panels and a base panel. The construction of the panels is the same for all footbridge sizes but with changes in the lengths and widths (heights) of panels and some changes in section sizes.

This Appendix contains step-by-step instructions for construction of a footbridge with working drawings for manufacture of all the components. In order to provide a self-contained set of instructions some details from Chapter 5 are repeated here.

In order to cover the range of footbridge sizes the overall dimensions are given in terms of the – Modular Length (ML); Modular Height (H); and Modular Width (W). These dimensions are obtained from Tables B1 and B2.

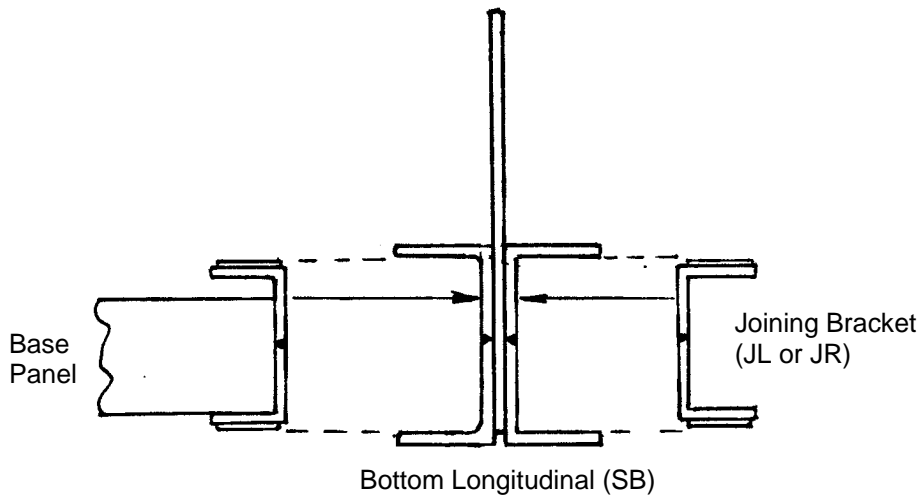
Brackets are provided on the drawings for the construction supervisor to fill in the specific dimensions for the workshop technicians.

Panels and Modules have to be bolted together on site to assemble the footbridge. It is therefore **very important** that a systematic approach is used in construction to ensure that panels fit together without problems. The following instructions are important.

MANUFACTURING NOTES:

1. In the manufacture of the panels described below, **ALL bolt holes must be drilled BEFORE the panels are assembled and welded. Joining parts must be clamped together for drilling to ensure holes line up.**
2. All members should be **clearly marked** using the panel index from Figure B1 and the assembly drawings. This should ensure that panels match up and bolt together without problems. Marking should be with weld deposit or punch as chalk or paint may rub off.
3. The Joining Brackets (JL and JR) and the Longitudinals of the Base Panels (BL) have to fit inside the Base Longitudinals of the End Panels (EB) and Side Panels (SB) as shown below. Check this is satisfactory before welding. Leave gaps of 1 or 2mm between the angles for EB and SB and weld in the gap
4. Welding of the panels **MUST** be carried out using an assembly jig and **MUST** be done in sequence starting from the Left or Right Hand end of the bridge. Joining members **MUST** be bolted together during the welding up of the panels to make sure holes line up when the footbridge is being assembled.

5. The strength of the footbridge depends on the joints of the panels being **fully and properly welded**. Make sure all joints are fully welded all round with good penetration of the welds. Note in particular that angle sections (verticals and diagonals) must be welded both to the gussets at the joints **and also to the joining channels or angles**.



The Joining Brackets and Base Panels must fit inside the channels of the Bottom Longitudinals so that the faces bolt together without gaps

Construction Details of Footbridge

The guidelines for construction of a footbridge are presented as follows:

- Figure B1: Details of Footbridge Modules
- Figure B2: Assembly of Panels
- Table B1: Numbers and Lengths of Modules needed for Range of Spans

STAGE 1: *Construction of Side Panel Members*

- Figure B3: Details of Side Panel Members
- Table B2: Parts List for Side Panel
- Figure B4: Manufacture of Side Panel Members (Sheets 1, 2 and 3)

STAGE 2: *Construction of End Panel Members*

- Figure B5: Details of End Panel Members
- Table B3: Parts List for End Panel
- Figure B6: Manufacture of End Panel Members (Sheets 1 and 2)

STAGE 3: *Construction of Base Panel Members*

- Figure B7: Details of Base Panel Members
- Table B4: Parts List for Base Panel
- Figure B8: Manufacture of Base Panel Members

STAGE 4: *Drilling of joining members*

Figure B9: Manufacture of Joining Bracket and Drilling Template

Figure B10: Drilling Template for Verticals and Base Panel Cross-Members

Figure B11: Drilling Procedure

STAGE 5: *Assembly and Welding Procedure*

Figure B12: Construction of Assembly Jig

Figure B13: Assembly and Welding Procedure (Sheets 1, 2 and 3)

STAGE 6: *Assembly and Testing of Footbridge*

B2: DETAILS OF FOOTBRIDGE MODULES

Figure B1: Shows the arrangement of modules

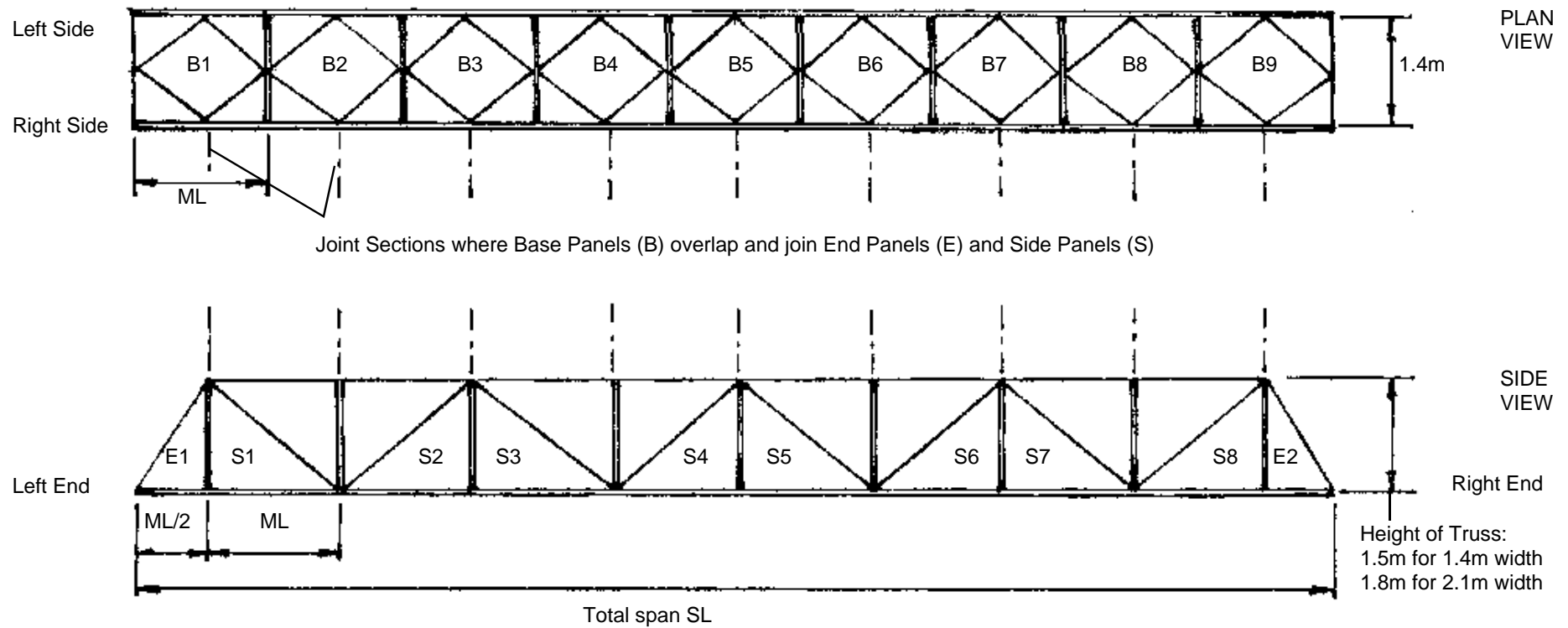
Figure B2: Shows how the panels are bolted together to form and join the modules

Table B1: Gives the number and lengths of the modules for the range of bridge spans in approximately 1m intervals. Note that the number of Side Panels always has to be EVEN for symmetry. The length of the End Panels is half that of the Side Panels.

Therefore Module Length ML = Bridge Length / (Number of Side Panels + 1)

Table B1: Numbers and Lengths of Modules for the Range of Spans

Span (m)	Number of Side Panels/side	Number of Base Panels	Length of Module (ML) m	Length of End Modules m
10	4	5	2.0	1.0
11	6	7	1.6	0.8
12	6	7	1.7	0.85
13	6	7	1.9	0.95
14	6	7	2.0	1.0
15	6	9	1.7	0.85
16	8	9	1.8	0.9
17	8	9	1.9	0.95
18	8	9	2.0	1.0
19	10	11	1.7	0.85
20	10	11	1.8	0.9



Panels Needed: End Panels (E) - 2 Left Side, 2 Right Side

Side Panels (S) - Even number; Note half have diagonal Top Left to Bottom Right
And half have diagonal Bottom Left to Top Right

Base Panels (B) - Number of side panels + 1

Note: The drawing shows 8 Side Panels. The actual number needed depends on the span, see Table B1.

Figure B1: Details of Modular Design

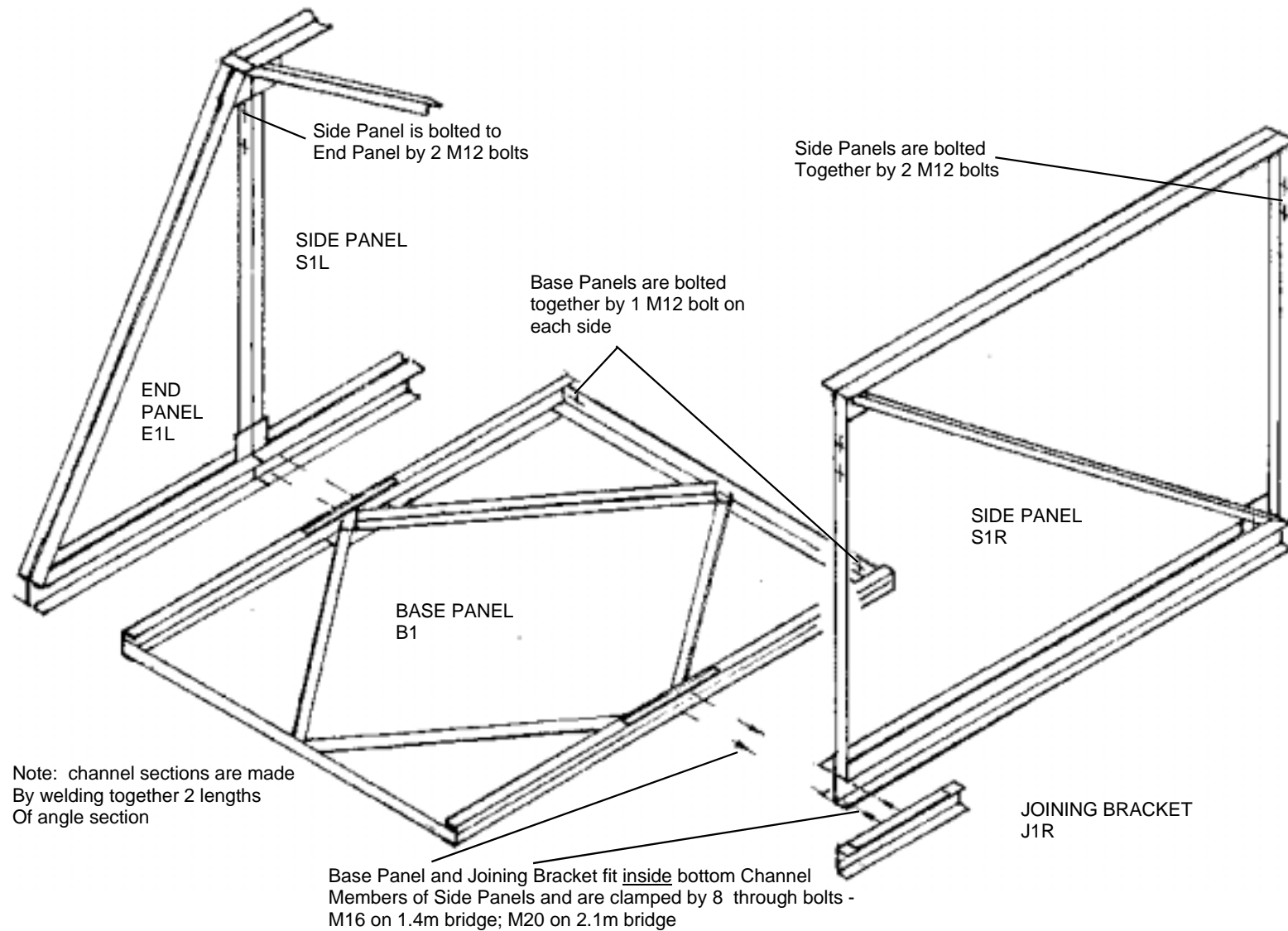


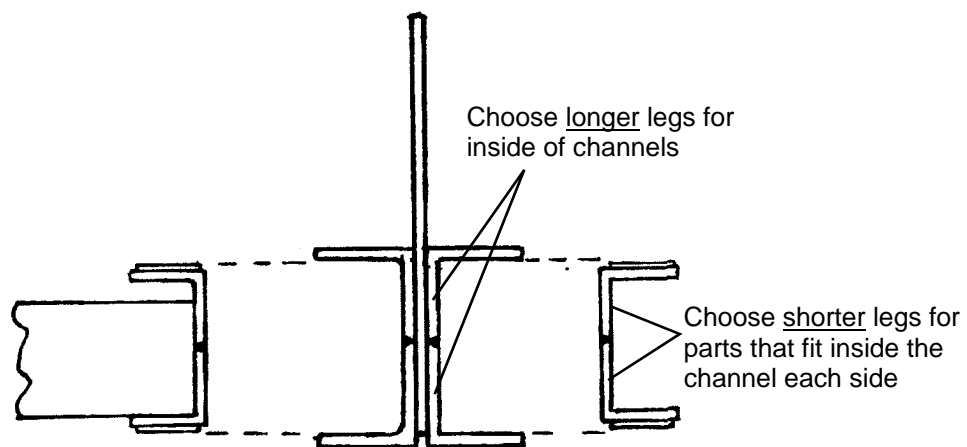
Figure B2: Details of Geometry and Assembly of Panels

B3: CONSTRUCTION DETAILS OF FOOTBRIDGE

Note:

Remember the Joining Brackets (JL and JR) and the Base Panel longitudinals (BL) have to fit inside the Side Panel longitudinals (SB) and End Panel longitudinals (EB). All these members are channel sections formed by welding 2 pieces of angle section together. Note that Joining Brackets and Base Panel longitudinals also have 3mm thick reinforcing strips welded on top and bottom.

Since the dimensions of angle section may vary slightly and may not be equal it is important to orientate the angle as shown in the sketch below and to check that the members fit together as specified.



If legs of angle are unequal, position them so they help in fitting the channels together

STAGE 1: Construction of Side Panel

Figure B3: Shows details of the Side Panel assembly and members. Note that on each side of the bridge half the Side Panels will have diagonals sloping from Top Left to Bottom Right and half Bottom Left to Top Right.

Table B2: Gives the materials list for a Side panel.

Table B2: Materials List for Side Panels (per panel)

Member	Materials for 1.4m wide footbridge			Materials for 2.1m wide footbridge		
	Section	Length mm	Number	Section	Length	Number
Bottom Longitudinals (SB)	50x50x6mm angle	ML	4	60x60x6 mm angle	ML	4
Top Longitudinals (ST)	60x60x6mm angle	(ML-12)mm (2)	2	60x60x6 mm angle	(ML-12)mm (2)	2
Verticals (SL & SR)	50x50x6mm angle	1450mm	2	50x50x6 mm angle	1750mm	2
Diagonals (SD) (1)	50x50x6mm angle	Measure and fit	2	50x50x6 mm angle	Measure and fit	2
Gusset SG1	60x6 flat bar	220 mm	1	60x6 flat bar	240 mm	1
Gusset SG2	60x6 flat bar	120 mm	2	60x6 flat bar	120 mm	1
Gusset SG3	60x6 flat bar	120 mm	1	60x6 flat bar	120 mm	1
Gusset SG4	60x6 flat bar	220 mm	2	60x6 flat bar	240 mm	1
Spacer SS	60 x 6 flat bar	40mm	2	60 x 6 flat bar	40mm	2

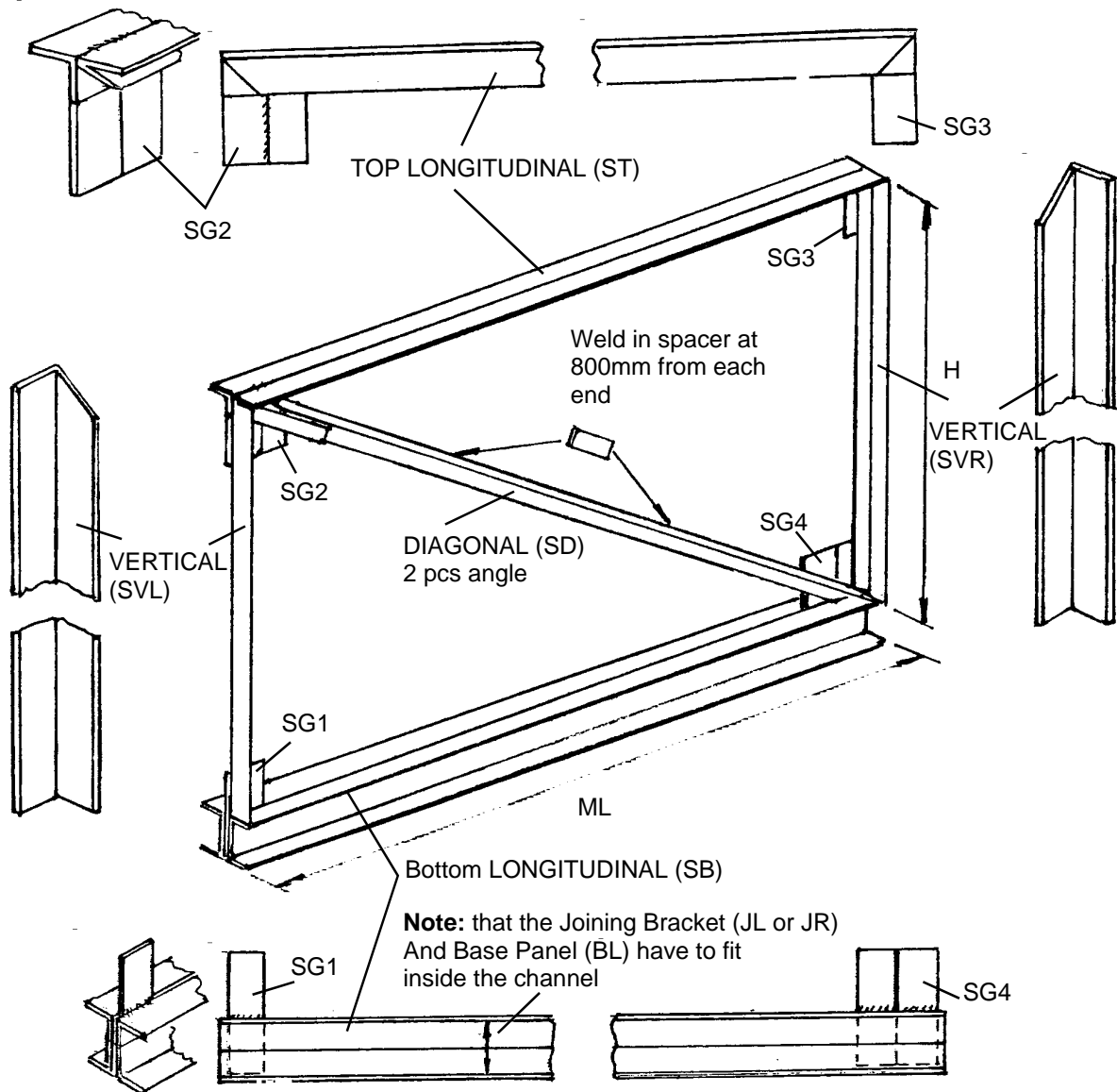
Notes: (1) The outside of the panel should be welded up first and then the required length of the diagonals measured. The approximate lengths for material requirements are:

1.4m wide bridge – 2.23m for ML= 1.7m, to 2.48m for ML = 2.0m

2.1m wide bridge – 2.45m for ML = 1.7m, to 2.66m for ML =2.0m

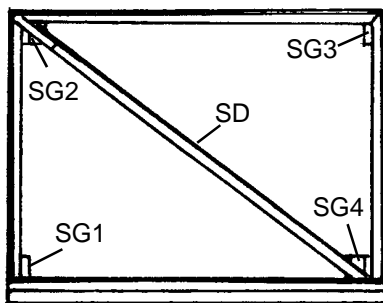
(2) The length is 2 thicknesses of angle (2 x 6mm) less than ML to allow for the Vertical members at each end.

Figure B4: Gives instructions for the manufacture of the members of the Side Panel. Note that drilling is carried out in STAGE 4 and assembly and welding in STAGE 5.

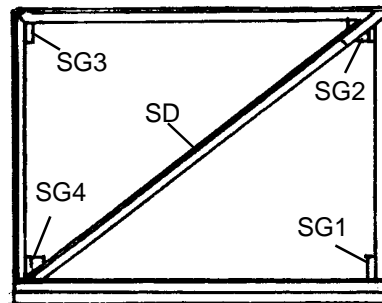


Note:

The number of Side Panels needed is given in Table B1. Half will have diagonals Sloping from top left to bottom right (Type A) and half bottom left to top right (Type B) as shown below



Side Panel A



Side Panel B

Side Views from OUTSIDE Bridge

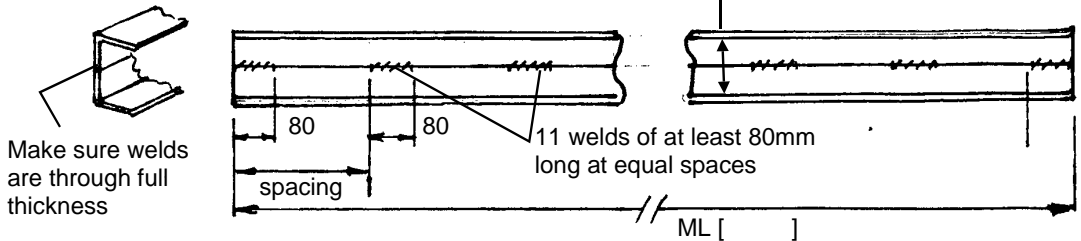
Figure B3: Details of Construction of Side Panel

1. **Bottom Longitudinal (SB)**

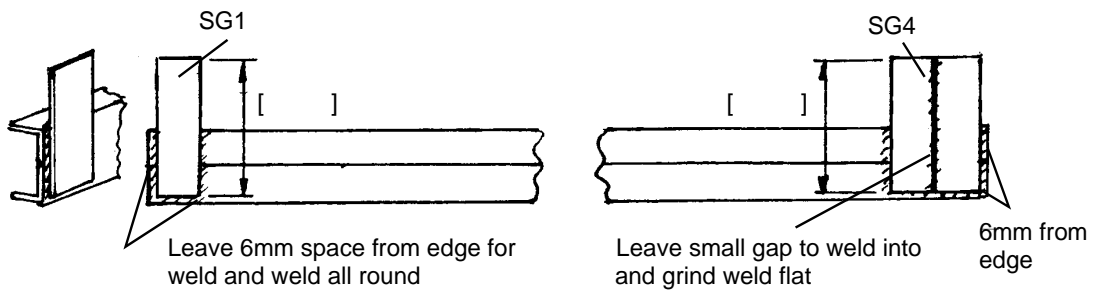
(Note: half as shown (A) and half with Gussets SG2 and SG3 reversed (b))

1.1 Cut 2 pcs angle (see Table B2) x ML long and stitch weld together to form channel section

Note: The Base Panel Longitudinals and Joining Brackets have to fit inside this space. Therefore check fit before welding. Leave 1 or 2m gap and weld into gap



1.2 Weld on Gussets from 60 x 6mm flat bar



1.3 Make up second channel as in 1.1 (this has no gussets attached)

1.4 Clamp second channel accurately in position to gussets of first and weld at gussets

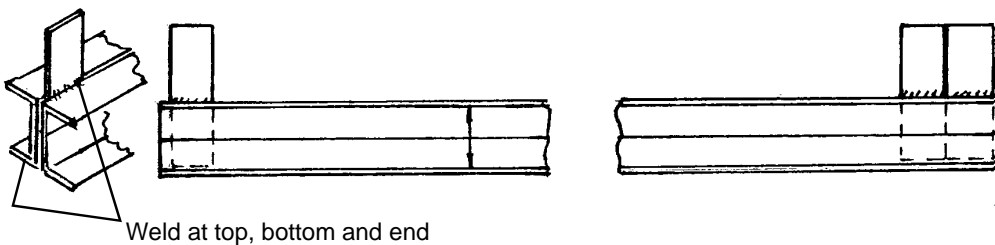
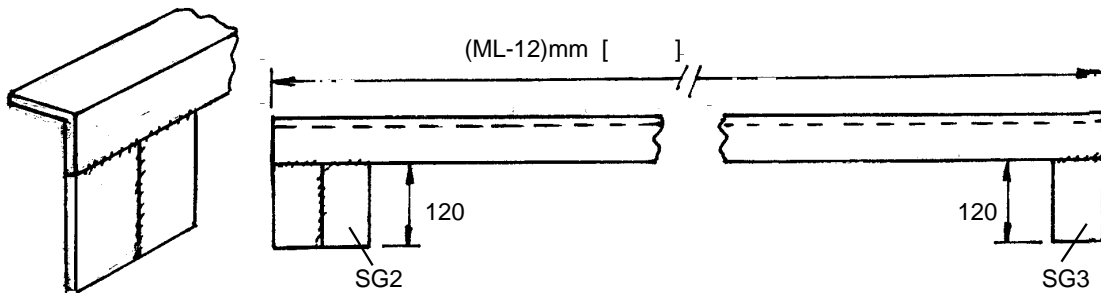


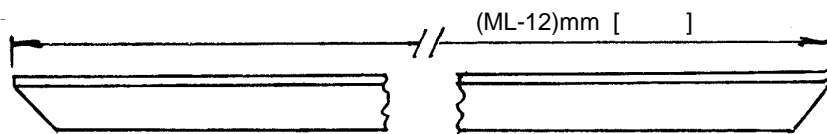
Figure B4 (Sheet 1): Manufacture of Members for Side Panels

2. Top Longitudinal (ST)

- 2.1 Cut length of 60 x 60 x 6 angle of length (ML-12)mm
Weld on gussets cut from 60 x 6mm flat bar



- 2.2 Cut second pc 60 x 60 x 6mm angle with 45° angles at each end for mitre joints with verticals.



- 2.3 Weld angle sections together along top and bottom joints.



3. Vertical members (SVL and SVR)

- 3.1 Cut 2 pcs 50 x 50 x 6mm angle to length H (see Table B2). Cut top end at 45° angle for Mitre joints with Top Longitudinal

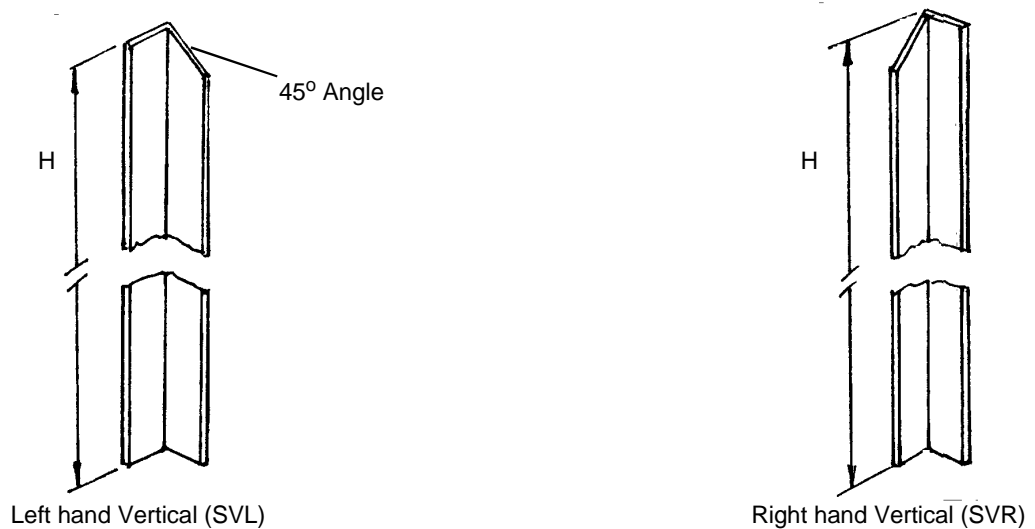
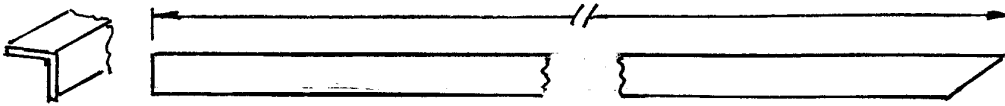


Figure B4 (Sheet 2): Manufacture of Members for Side Panels

4. **Diagonal (SD)** (Cut when panels are being assembled and welded in Stage 5)

4.1 Weld up outside frame of Side Panel and measure length of diagonal. Cut pc 50 x 50 x 6mm angle for deck side of panel for full length of diagonal.



4.2 Cut pc 50 x 50 x 6mm angle for Outside of panel. This is a little shorter than first pc since it fits on Gusset SG2 and butts up against the edges of the angles of the Top Longitudinal (SV) and Vertical (SV). Cut short length of 40 x 40 x 6mm angle to make up the full length into the corner joint..

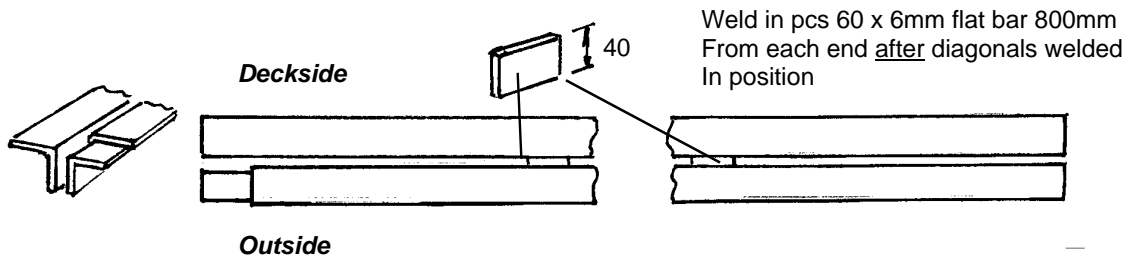
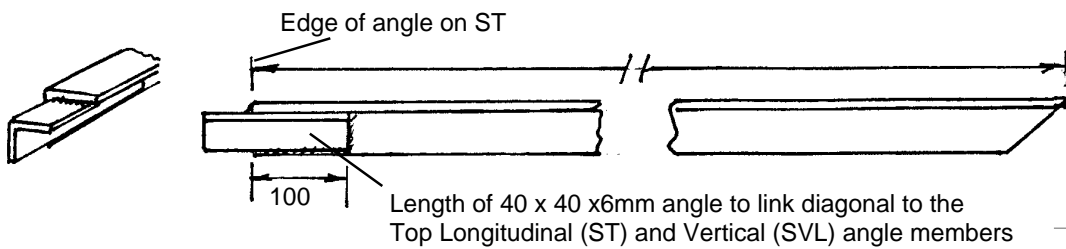


Figure B4 (Sheet 3): Manufacture of members for Side Panels

STAGE 2: Construction of End Panel

Figure B5: Shows the details of the End Panel assembly and members. Note that there are 4 End Panels. 2 have diagonals sloping bottom left to top right and 2 have bottom right to top left.

Table B3: Gives the materials list for an end panel.

Table B3: Materials List for End Panel (*Single panel*)

Member	1.4m Wide Footbridge			2.1m Wide Footbridge		
	Section	Length	Number	Section	Length	Number
Bottom Longitudinals (EB)	50x50x6mm angle	ML/2	4	60x60x6mm angle	ML/2	4
Vertical (EV)	50x50x6mm angle	1450mm	1	50x50x6mm angle	1750mm	1
Diagonal (ED)	50x50x6mm angle	Measure and fit (1)	2	60x60x6mm angle	Measure and fit	2
Gusset EG1	60x6 flat bar	210mm	1	60x6 flat bar	240mm	1
Gusset EG2	60x6 flat bar	260mm	1	60x6 flat bar	300mm	1
Gusset EG3	60x6 flat bar	220mm	2	60x6 flat bar	220mm	2
Gusset EG4	60x6 flat bar	180mm	1	60x6 flat bar	200mm	1

Note: (1) Weld the Vertical to the Base Longitudinal then measure up and cut the Diagonal to fit neatly into position. The approximate lengths for material requirements are:

1.4m footbridge – 1.68m for ML=1.7m to 1.77m for ML=2m
 2.1m footbridge – 1.95m for ML= 1.7m to 2.02m for ML = 2m

Figure B6: Shows details of the manufacture of the End Panel members.

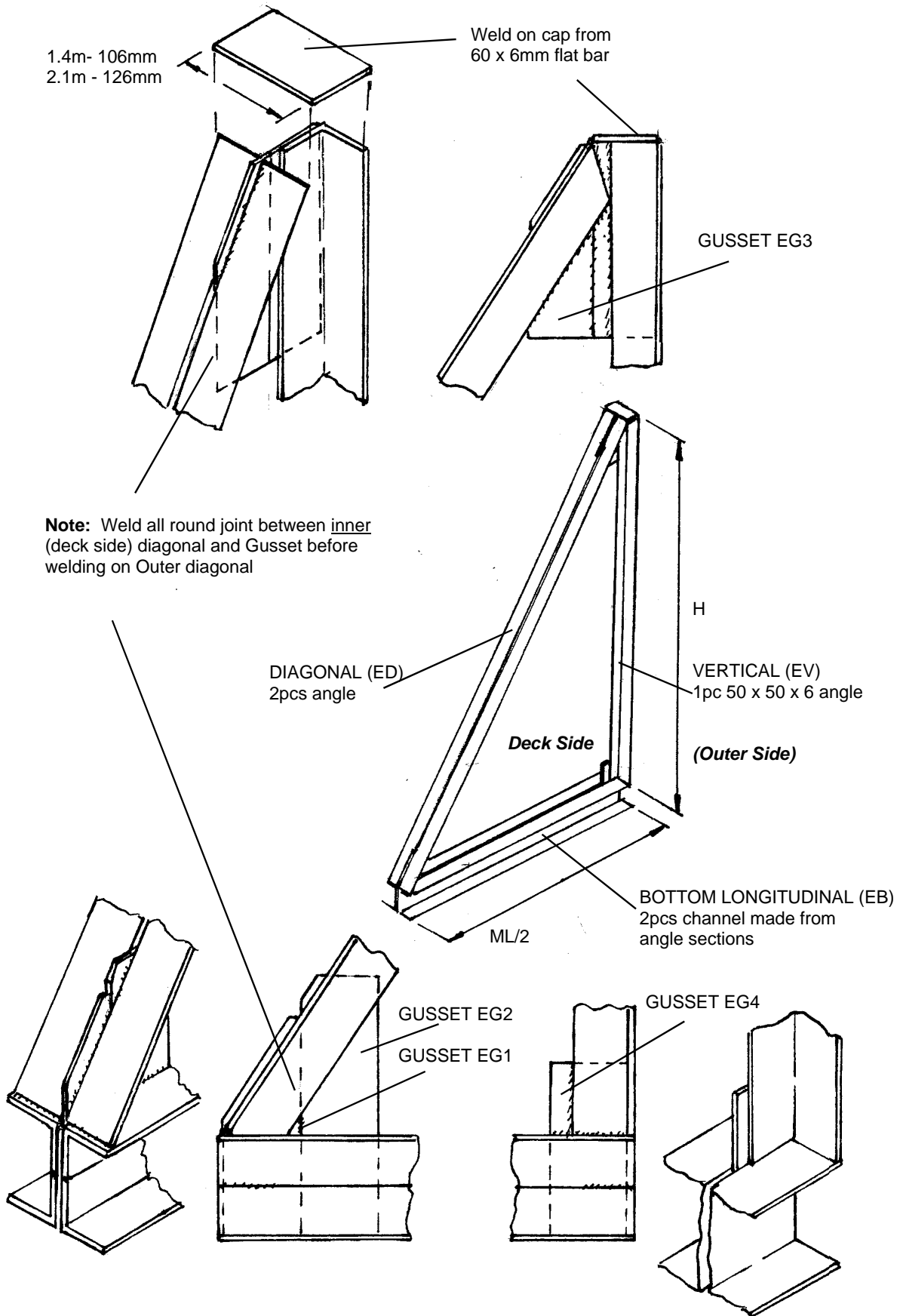
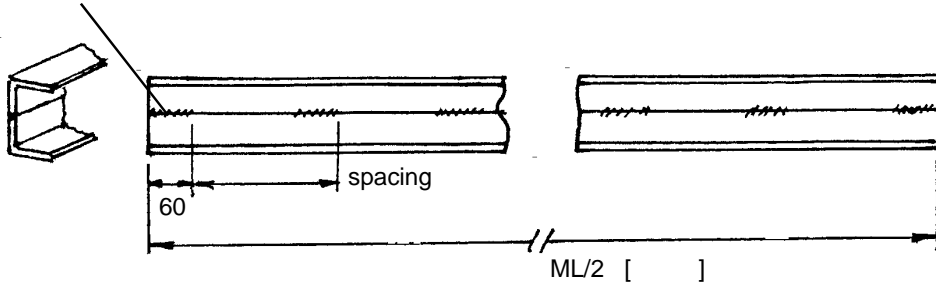


Figure B5: Details of Construction of End Panel (see Table B3 for materials)

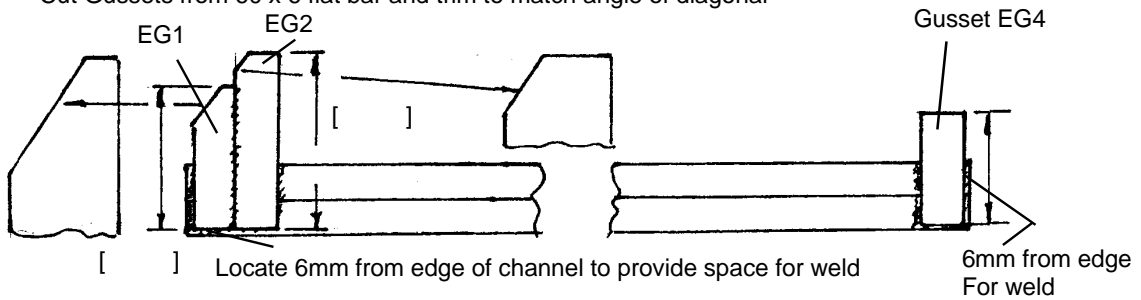
End Panel Members

1. **Base longitudinal (EB)** - 2 pcs channel made from angle sections (see Table B3)

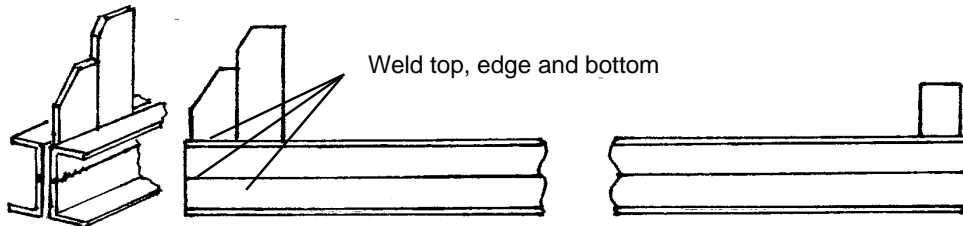
1.1 Cut 2 pcs angle x ML/2 (see Table B1) long and stitch weld to form channel. 8 welds at least 60mm long at equal spacing. Leave gap of 1 to 2mm between angle pieces to weld into



1.2 Cut Gussets from 60 x 6 flat bar and trim to match angle of diagonal



1.3 Make up second length of channel section as in 1.1 (this has NO gussets). Position accurately and weld to gusset plates



2. **Diagonal (ED)** - 2 pcs angle (see Table B3). Measure and cut to length during assembly (Stage 5)

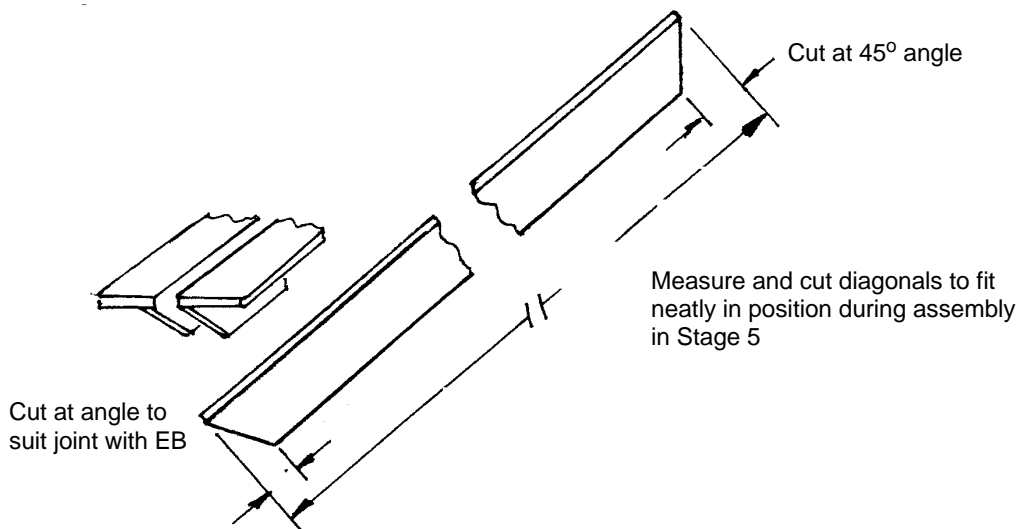
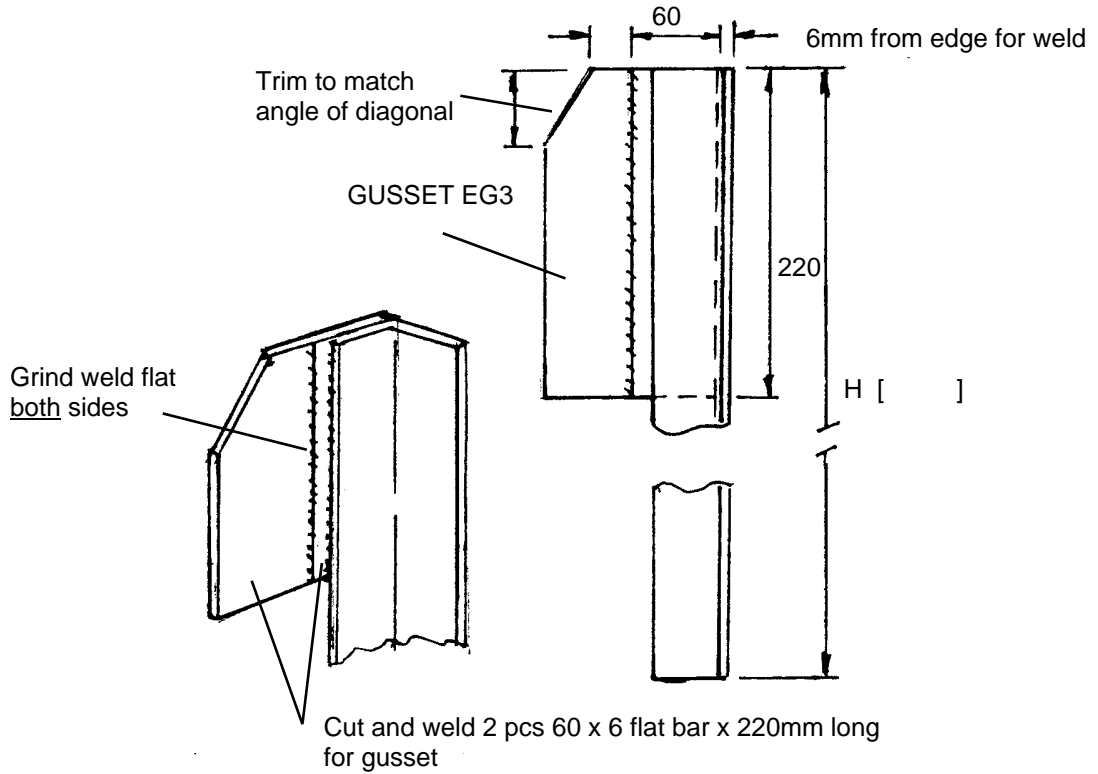
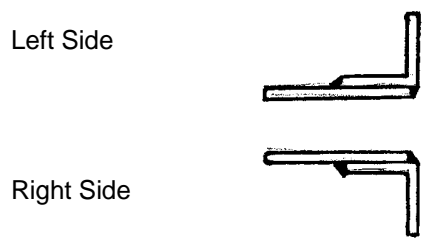


Figure B6 (Sheet 1): Members for End Panel

- 3. **Vertical (EV)** - 1 pc 50 x 50 x 6mm angle
- 3.1 Cut pc of angle of length H (see Table B3)
- 3.2 Cut 2 pcs of 60 x 6 flat for Gusset EG3 and weld in position



Note: A LH and RH Vertical are needed for each End Panel as shown below



VIEW ON TOP OF VERTICALS

Figure B6 (Sheet 2): Members for End Panel

STAGE 3: Construction of Base Panel

Figure B7: Shows the details of the Base Panel assembly and members. The length of the Panel (ML) is obtained from Table B1 and the width from Table B4.

Table B4: Gives the materials list for a Base Panel

Table B4: Materials List for Base Panel (Single Panel)

Member	1.4m Wide Footbridge			2.1m Wide Footbridge		
	Section	Length	Number	Section	Length	Number
Bottom Longitudinals (BL)	40x40x6mm angle	ML	4	50x50x6mm angle	ML	4
Stiffeners for longitudinal	30x3 flat bar	500mm	4	40x3 flat bar	500mm	4
Diagonals (BD)	50x50x6mm angle	Measure and fit (1)	4	60x60x6mm angle	Measure and fit	2
Cross members (BC)	60x60x6mm angle	1486mm	2	60x60x6mm angle	2186mm	2
Gusset BG1	60x6 flat bar	200mm	2	60x6 flat bar	200mm	2

Note: (1) Weld the outside of the panel, longitudinals and cross members, then measure and cut the diagonals to fit. The approximate lengths for material requirements are:

1.4m footbridge – 1.1m for ML = 1.7m to 1.3m for ML = 2.0m
 2.1m footbridge – 1.3m for ML = 1.7m to 1.5m for ML = 2.0m

Figure B8: Shows the details of the manufacture of the members of the Base Panel.

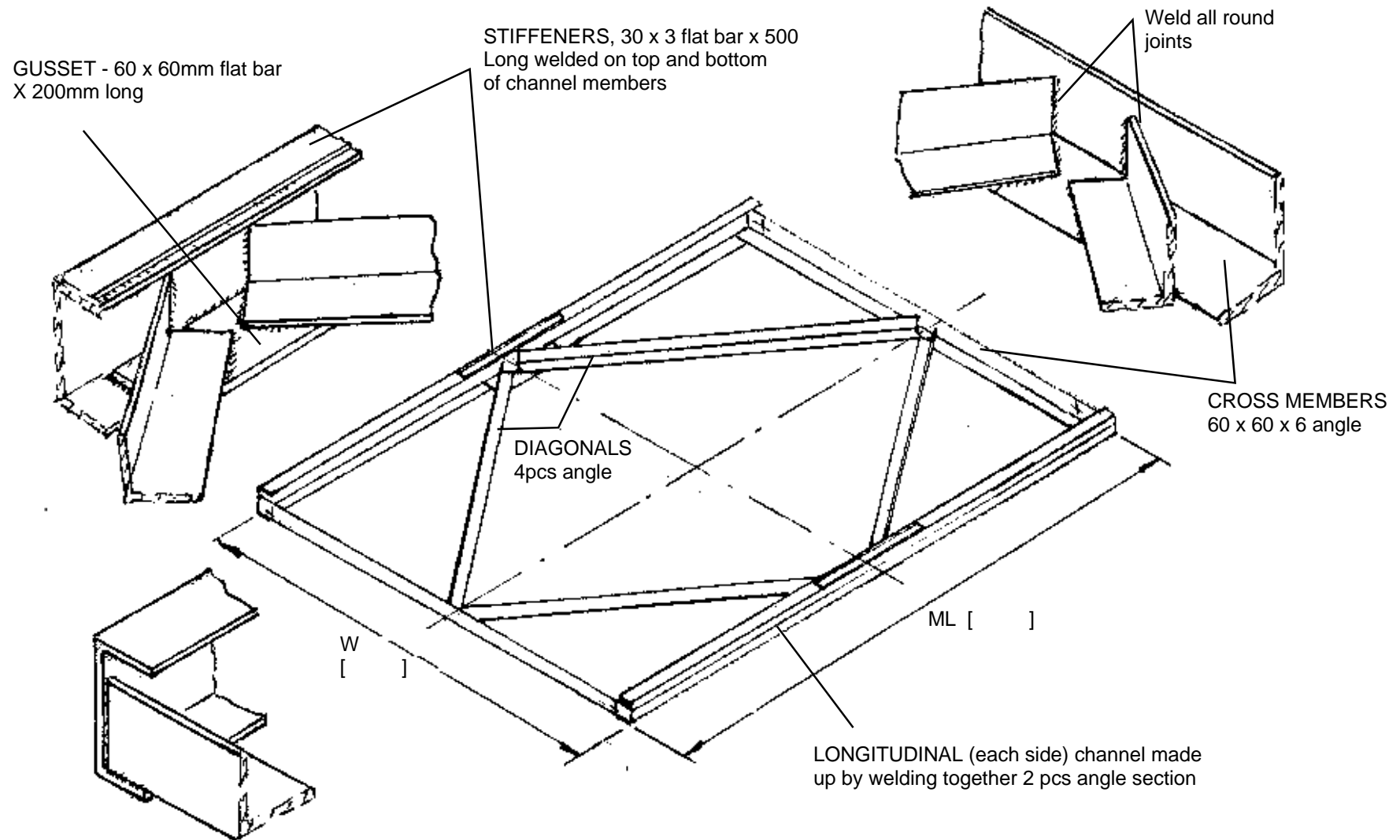
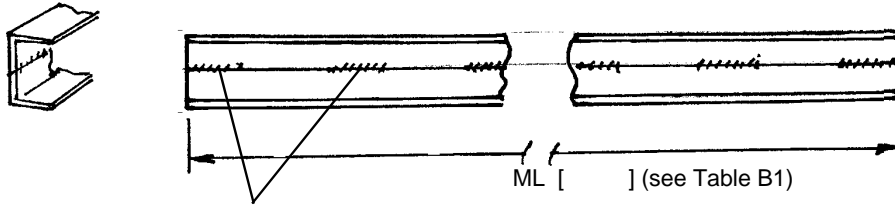


Figure B7: Details of Base Frame

Base Frame Members

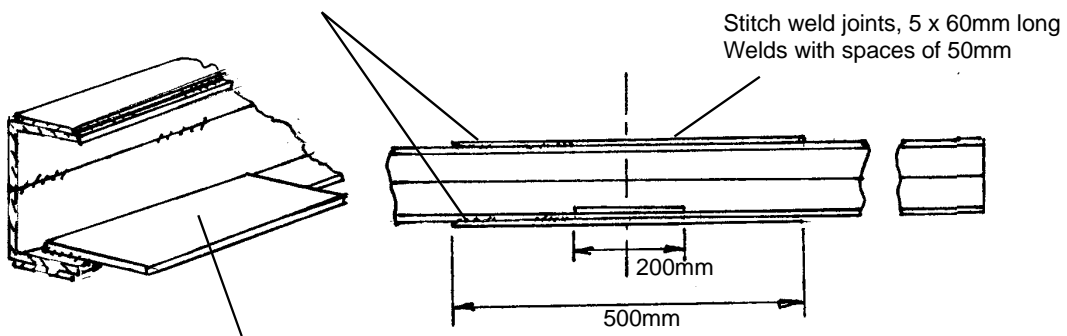
1. Longitudinals (BL)

1.1 Cut 2 lengths angle (see Table B4) and stitch weld together to form channel section. 2 pcs needed



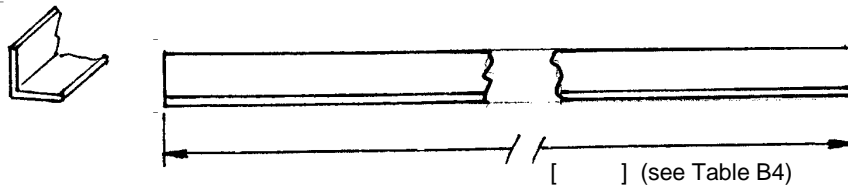
Stitch weld - 11 welds at least 60mm long at equal spacing

1.2 Weld on stiffeners, 30 x 3 flat bar x 500 long, top and bottom at centre of longitudinal.



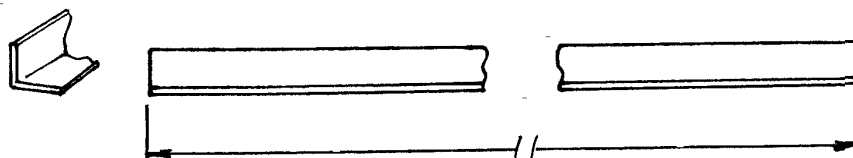
Weld on gusset, 60 x 6mm flat bar x 200mm long, at centre of bottom flange of channel

2. Cross-Members (BC)



2 pcs 60 x 60 x 6 angle

3. Diagonals (BD)



Measure and cut to fit during assembly (Stage 5)

4 pcs angle (see Table B4)

Figure B8: Members for Base Panel

STAGE 4: Construction of Joining Brackets and drilling of Joining Members.

Figure B9: Shows the details of the construction of the Joining Brackets (JL and JR) and of the drilling template needed for drilling the holes for bolting the modules together.

Table B5: Gives the materials list for the Joining Bracket

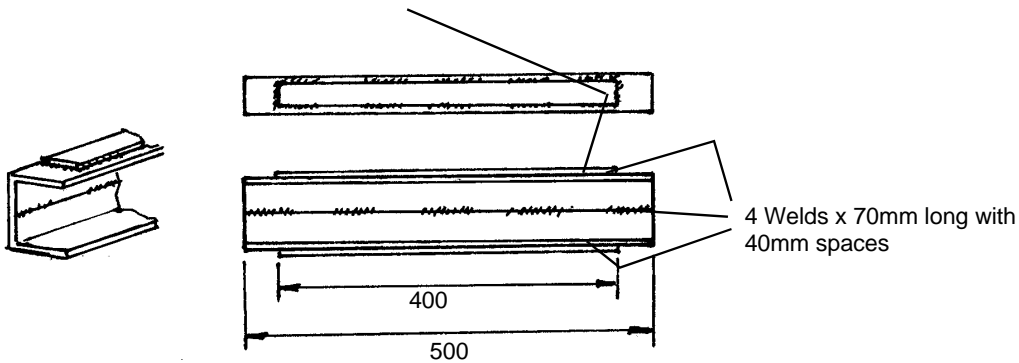
Table B5: Materials List for Joining Bracket

Member	1.4m Wide Footbridge			2.1m Wide Footbridge		
	Section	Length	Number	Section	Length	Number
Joining bracket	40x40x6mm angle	500mm	2	50x50x6mm angle	500	2
Stiffeners for bracket	30x3 flat bar	400mm	2	40x3 flat bar	400mm	2
Joining bolts/joint	M16	50mm	8	M20	50mm	8

Figure B10: Shows the details of the construction of the templates for drilling the Vertical members of the Side Panels (SV) and the cross-members of the Base Panels (BC).

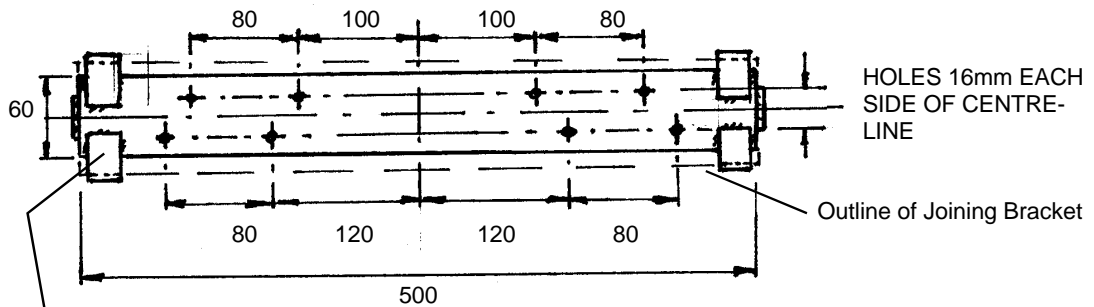
1. Joining Bracket

- 1.1 Cut 2 pcs angle (see Table B5) x 500mm and stitch weld to form channel
- 1.2 Weld on stiffeners, 30 x 3 (or 40 x 3) flat bar x 400mm long on top and bottom

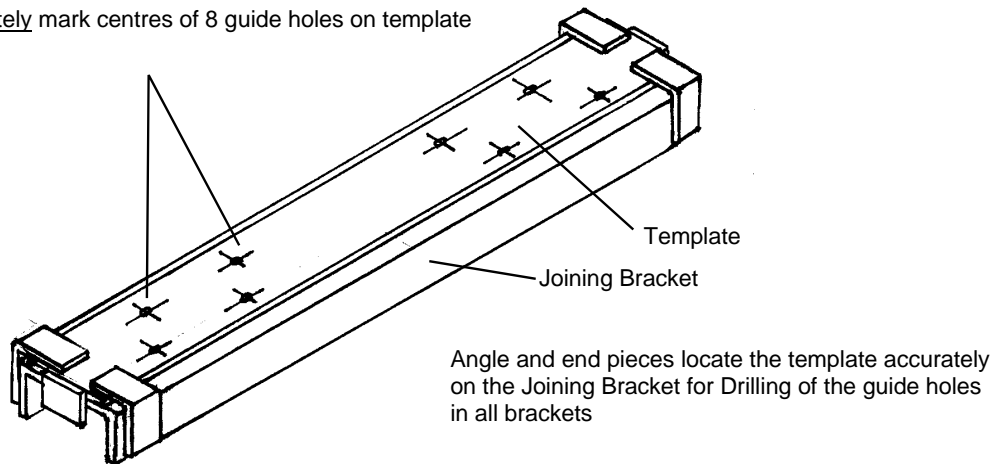


2. Drilling Template for Side Panel Joints (1 needed)

- 2.1 Cut pc 60 x 6mm flat bar x 500mm long



- 2.2 Weld on 4 pcs 40 x 40 x 6mm angle x 25mm long to locate the template centrally on the Joining Bracket
- 2.3 Weld on pc 30 x 3mm flat bar x 25mm long at each end of template
- 2.4 Accurately mark centres of 8 guide holes on template

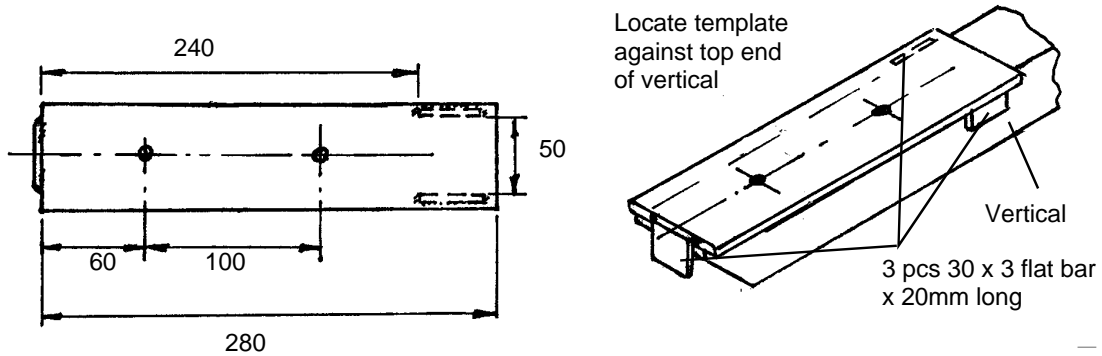


- 2.5 Drill guide holes 6 to 8mm diameter

Figure B9: Details of Joining Bracket and Drilling Template

3. Template for Drilling Vertical Members (1 needed)

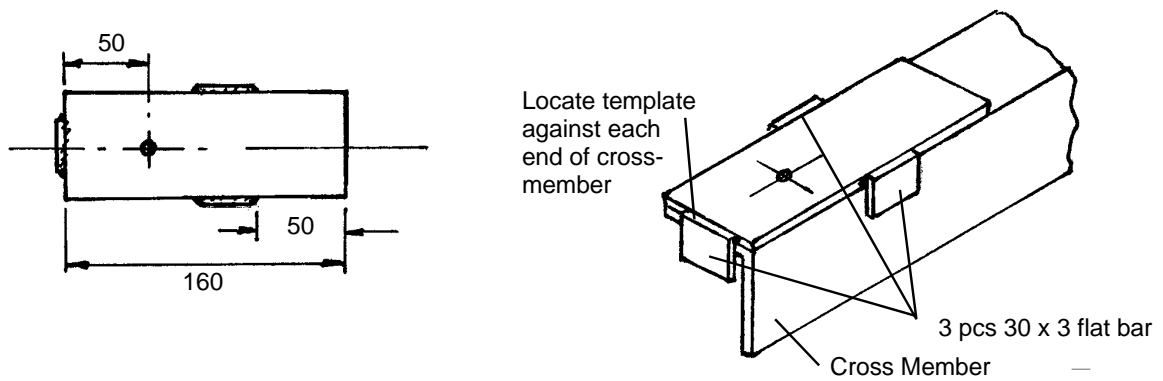
3.1 Cut pc 60 x 6mm flat bar x 280mm long



3.2 Weld on 3 pcs 30 x 3 flat bar x 20mm long to locate template on 50 x 50 x 6mm angle.

3.3 Accurately mark centres of 2 guide holes and drill 6 to 8mm diameter

4. Template for Drilling Cross Members of Base Panel (1 needed)



4.1 Cut pc 60 x 6mm flat bar x 160mm long

4.2 Weld on 3 pcs 30 x 3 flat bar x 20mm long to locate template on 60 x 60 x 6 angle cross-member

4.3 Accurately mark centre of guide hole and drill 6 to 8mm diameter

Figure B10: Details of Templates for Drilling Vertical Members of Side Panels and Cross-Members of Base Panels

5. Drill holes for joining Side Panels - starting at LH end

The panels and modules are bolted together by 8 bolts at each joint between the modules on each side of the footbridge as indicated in Figures B1 and B2.

At each joint an End Panel and Side Panel OR 2 Side Panels are bolted together by a Joining Bracket and Base Panel. The End and Side Panels are bolted together at their Bottom Longitudinals.

It is essential that the parts that bolt together are drilled together to ensure that bolt holes line up during assembly of the bridge. Drilling must be done before the panels are welded up. All parts must be clearly and permanently marked so parts are assembled in the same combination as they are drilled. There is no interchangeability of parts.

The procedure is explained in the steps below. This follows the order of modules shown in Figure B1. The joining parts at each joint are clamped accurately together and then pilot holes of 6 to 8mm diameter are drilled. Holes are then opened up to the required size:

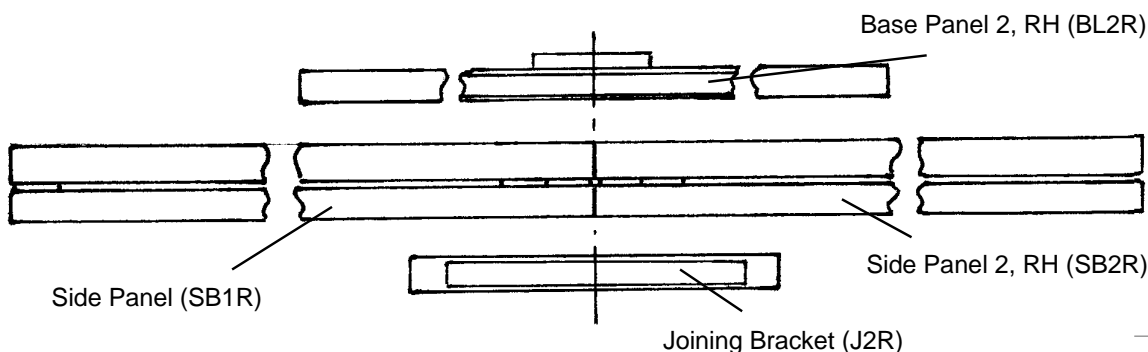
- 17mm for M16 bolts for 1.4m wide bridge
- 21mm for M20 bolts for 2.1m wide bridge



Joint between End Panel and Side Panel 1 (Right Side)

- 5.1 Use drilling template to drill guide holes in Joining Bracket J1.R (Number 1, Right Side).
- 5.2 Accurately mark the centre lines of the Base Panel and Joining Bracket and line up with the joint of End and Side Panels. Firmly clamp the 4 members together.
- 5.3 Drill through the guide holes in the Joining Bracket.
- 5.4 Remove clamps and drill out each hole to **17mm** diameter (1.4m wide bridge) or **21mm** (2.1m wide) in 2 or 3 stages.
- 5.5 Repeat Steps 1.1 to 1.4 to LH side members of Module.
- 5.6 Move on to joint between Modules 1 and 2

Figure B11 (Sheet 1): Procedure for Drilling Bolt Holes



- 5.7 Repeat Steps 5.1 to 5.4 for RH members shown in sketch and also for LH members.
- 5.8 Continue working in pairs of members as above to RH end of footbridge. The procedure is summarised in Table B6.

Note:

Make sure the Gussets on the Bottom Longitudinals are in the correct order for the diagonals. The diagonals attach to the double gusset. The slopes of the diagonals are shown by / and \ in Table B6 looking from the right side of the bridge as in Figure B1

Table B6: Procedure for Drilling Holes for Joining Bolts

RIGHT HAND SIDE OF BRIDGE				LEFT HAND SIDE OF BRIDGE			
Joint – see Figure B1	Members that are clamped and drilled together			Joint – see Figure B1	Members that are clamped and drilled together		
	End and/or Side Bottom Longitudinals	Joining Bracket	Base Panel Longitudinal		End and/or Side Bottom Longitudinals	Joining Bracket	Base Panel Longitudinal
E1.R to S1.R	EB1.R + SB1.R / \	J1.R	BL1.R	E1.L to S1.L	EB1.L + SB1.L / \	J1.L	BL1.L
S1.R to S2.R	SB1.R + SB2.R \ /	J2.R	BL2.R	S1.L to S2.L	SB1.L + SB2.L \ /	J2.L	BL2.L
S2.R to S3.R	SB2.R + SB3.R / \	J3.R	BL3.R	S2.R to S3.R	SB2.L + SB3.L / \	J3.L	BL3.L
S3.R to S4.R	SB3.R + SB4.R \ /	J4.R	BL4.R	S3.R to S4.R	SB3.L + SB4.L \ /	J4.L	BL4.L
S4.R to S5.R	SB4.R + SB5.R / \	J5.R	BL5.R	S4.R to S5.R	SB4.L + SB5.L / \	J5.L	BL5.L
S5.R to S6.R	SB5.R + SB6.R \ /	J6.R	BL6.R	S5.R to S6.R	SB5.L + SB6.L \ /	J6.L	BL6.L
S6.R to S7.R	SB6.R + SB7.R / \	J7.R	BL7.R	S6.R to S7.R	SB6.L + SB7.L / \	J7.L	BL7.L
S7.R to S8.R	SB7.R + SB8.R \ /	J8.R	BL8.R	S7.R to S8.R	SB7.L + SB8.L \ /	J8.L	BL8.L
S8.R to E2.R	SB8.R + EB2.R / \	J9.R	BL9.R	S8.R to E2.R	SB8.L + EB2.L / \	J9.L	BL9.L

Note:

This is the procedure for 9 modules (8 full modules + 2 end modules). The procedure for less or more modules follows the same pattern.

Figure B11 (Sheet 2): Procedure for Drilling Bolt Holes

6. Drill holes in Side Panel Verticals and Base Panel Cross-Members

- 6.1 Locate correct template accurately on each member (see Figure B10) and drill through guide hole(s).
- 6.2 Drill out each hole to **13mm** diameter.
- 6.3 Drill the holes in the vertical members for the side braces (STAGE 6).

Bolt the joining members together as shown below and drill 13mm hole for an M12 bolt at position shown.

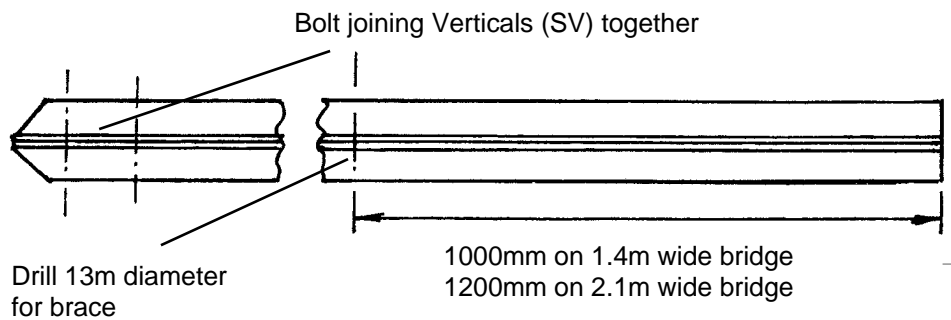


Figure B11 (Sheet 3): Procedure for Drilling Bolt Hole

STAGE 5: Construction of Assembly Jigs and Assembly of Panels

It is essential that panels are assembled and welded up on a jig to ensure shape and size are consistent.

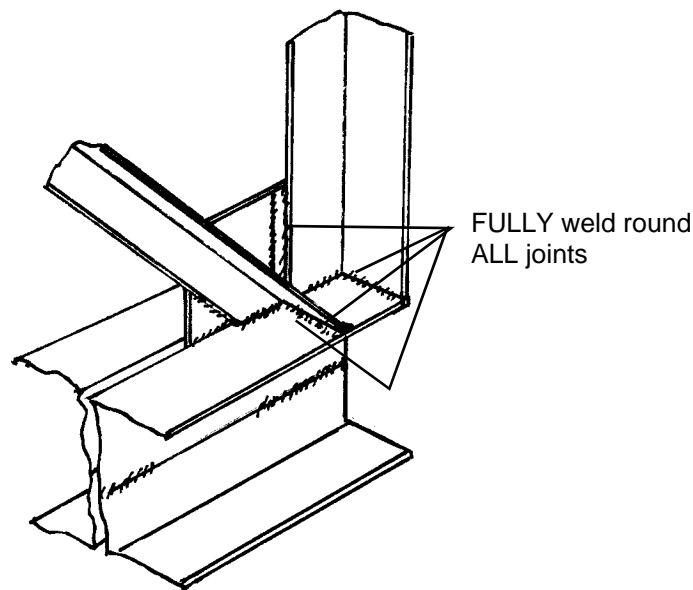
Joining parts must be bolted together before welding to ensure holes line up when the panels are assembled.

Figure B12: Shows the details of the assembly jigs

Figure B13: Shows the assembly and welding up of the base panels

Figure B14: Shows the assembly and welding up of the side panels

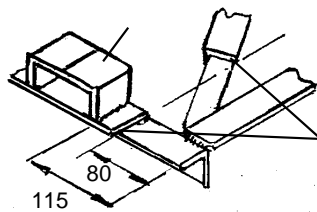
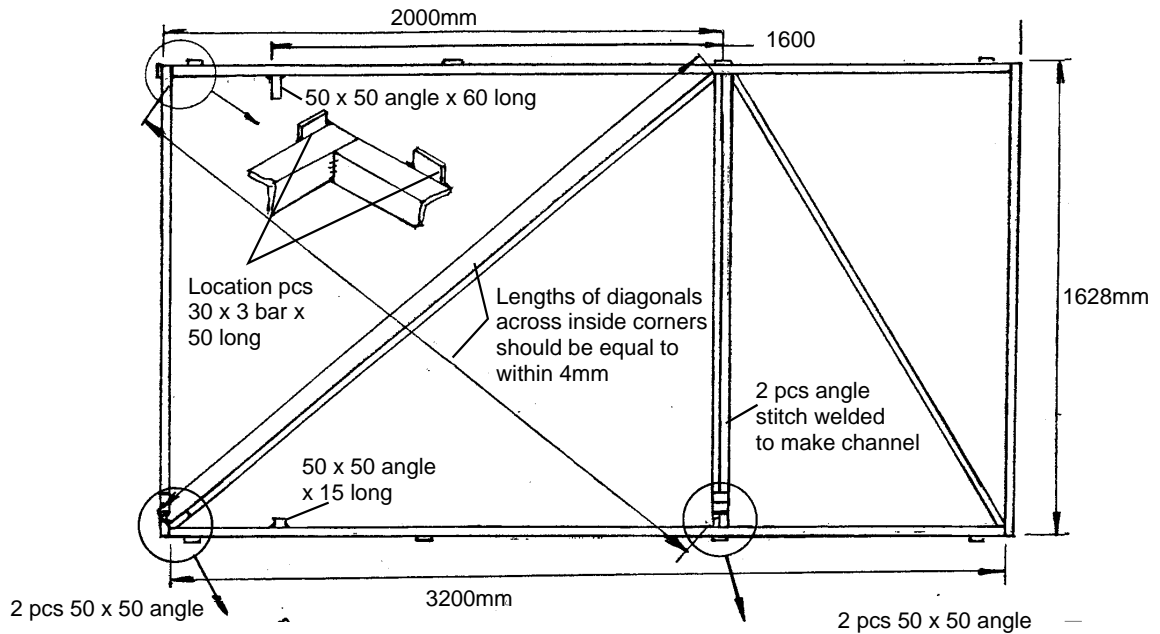
Note: The assembled panels are shown set up on the jig. The members are shaded so that they show up clearly.

Welding Instructions

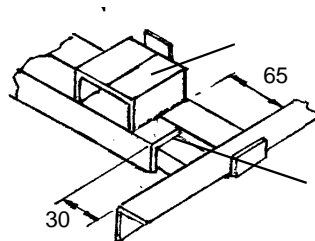
When the panel has been tack-welded and checked for correctness ALL joints should be fully Welded.

It is important to weld BOTH between Members and Gussets and also between the Members (angle to angle, angle to channel).

1. Cut main frame members from 50 x 50 x 6 angle and tack weld, checking all corners are square
2. Build jig on a flat surface so that top face for assembling panels is flat.
3. Check lengths of diagonals and when within 4mm, cut and weld in diagonals.
4. Weld up frame



Cut 50 x 50 angle and
weld in 160mm length
of 40 x 40 angle



Cut 50 x 50 angle and
weld in pc 40 x 40
angle x 100mm long

(i) Jig for 1.4m Wide Footbridge

Figure B12 (Sheet 1): Details of Assembly Jigs

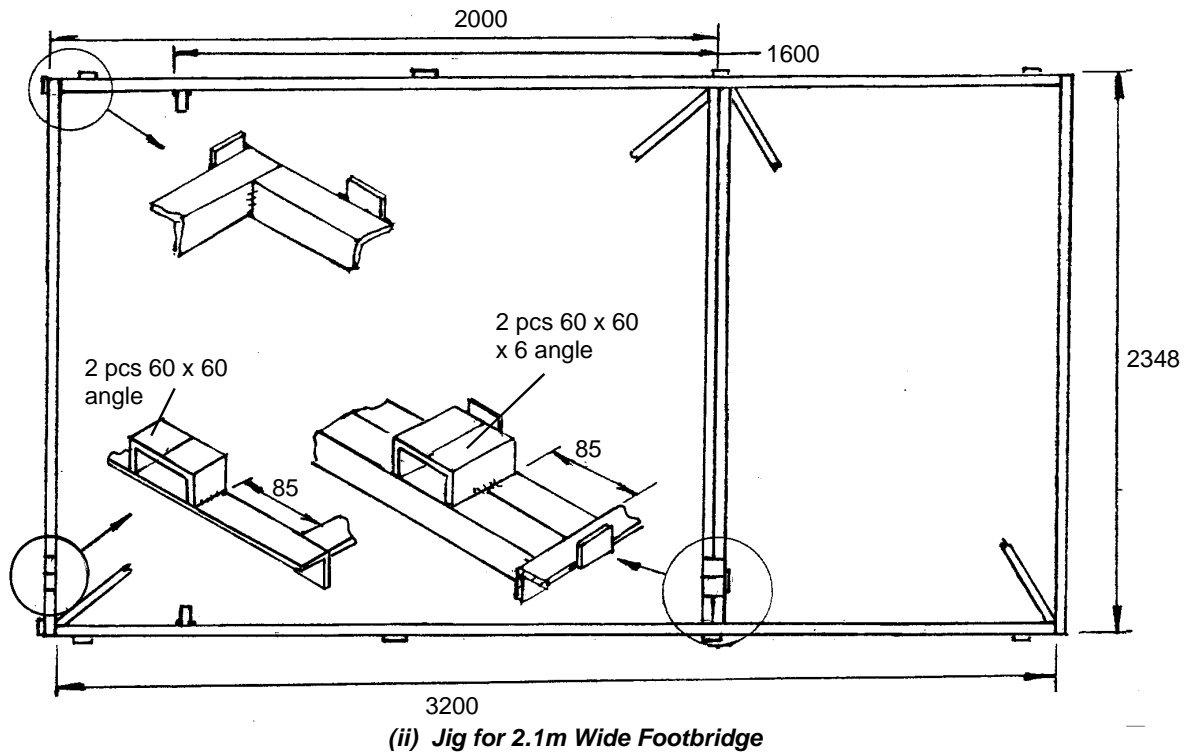


Figure B12 (Sheet 2): Details of Assembly Jigs

STAGE 5.1: Assembly of Base Panels**STEP 1: Assembly of Base Panels B1 and B2 (Left Hand End)**

- 1.1 Bolt together: Left Side – SB1.L, SB2.L, J2.L, BL1.L, BL2.L
Right Side – SB1.R, SB2.R, J2.R, BL1.R, BL2.R
- 1.2 Clamp the Left side and Right side assemblies on the jig, accurately lining up the joint between SB1 and SB2 on the joint position on the jig on each side.
- 1.3 Bolt together the joining Cross Members for Base Panels 1 and 2 (BC1.R, BC2.L). Position accurately in the jig at the joint of the Base Panels and tack weld both in position on their respective base frames.
- 1.4 Position Cross Member BC1.L (undrilled member) at left hand end of Base Panel 1 and tack weld in position.
- 1.5 Unbolt joints to remove Base Panel 1 and Side Bottom Longitudinals SB1.L and SB1.R.
- 1.6 Measure, cut and fit diagonals for Base Panel 1 and complete welding up. All joints must be fully welded.

STEP 2: Assembly of Base Panels B2 and B3

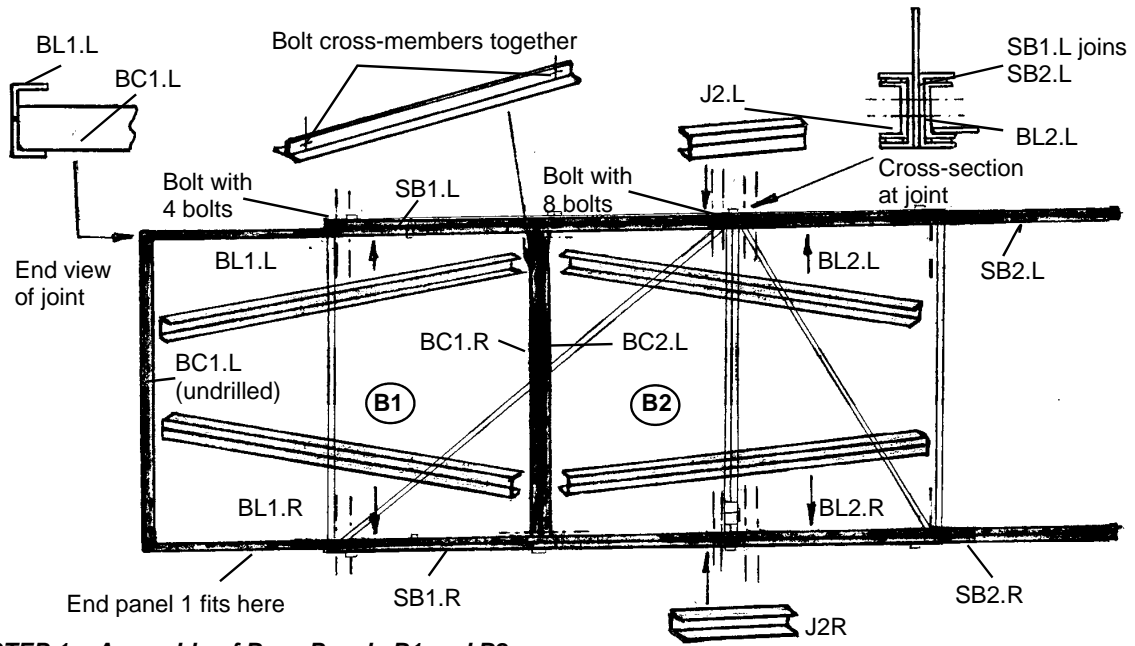
- 2.1 Bolt together: Left Side – SB2.L, SB3.L, J3.L, BL2.L, BL3.L
Right Side – SB2.R, SB3.R, J3.R, BL2.R, BL3.R
- 2.2 Clamp Left and Right assemblies on jig, accurately lining up joints between SB2 and SB3 on the joint positions on the jig.
- 2.3 Bolt together Cross Members BC2.R and BC3.L. Locate accurately in position and tack weld them to their respective Base Frames.
- 2.4 Unbolt joints to remove Base Panel B2 and bottom longitudinals SB2.L and SB2.R.
- 2.5 Fit diagonals and complete welding up Base Panel B2.

STEPS 3 to 9 Assembly of Base Panels B4 – B9 (If there are 10 Side Panels).

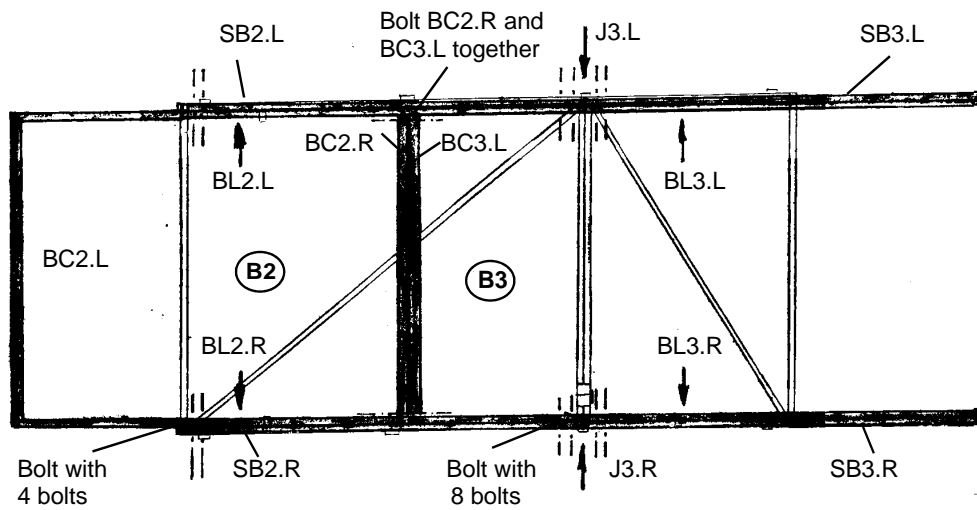
Repeat Step 2 for each joint in sequence to the right hand of the bridge.

STEP 10: Assembly of Base Panels B10 and B11 (Right Hand End)

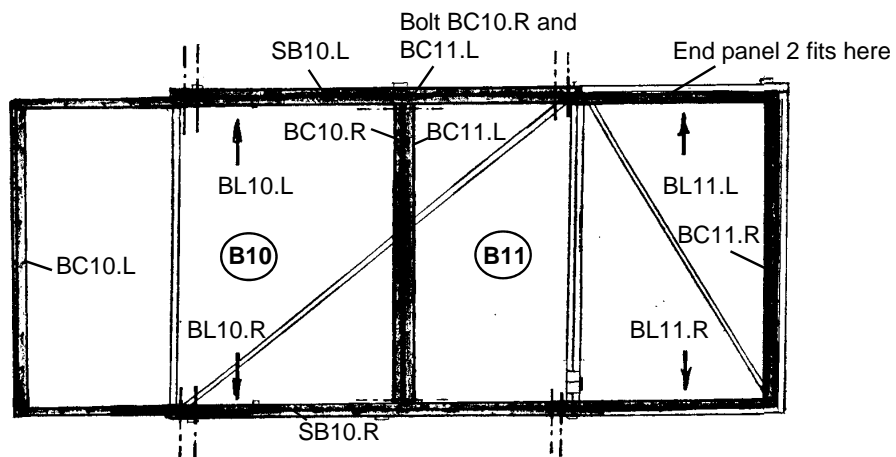
- 10.1 Bolt together: Left Side – SB10.L, J11.L, BL10.L, BL11.L.
Right Side – SB10.R, J11.R, BL10.R, BL11.R.
- 10.2 Clamp Left and Right assemblies on jig.
- 10.3 Bolt together Cross Members BC10.R and BC11.L. Fit in position and tack weld them to their respective base panels.
- 10.4 Fit end Cross Member, BC11.R, (undrilled) and tack weld in position.
- 10.5 Unbolt joints, measure and cut diagonals for the 2 base panels. and complete welding of Base Panels B10 and B11.



STEP 1: Assembly of Base Panels B1 and B2



STEP 2: Assembly of Base Panels B2 and B3



STEP 10: Assembly of Base Panels B10 and B11

Figure B13: Assembly of Base Panels

STAGE 5.2: Assembly of Side Panels (Left Side)**STEP 1: Assembly of End Panel E1 (Left End)**

- 1.1 Bolt together EB1.L, J1.L and SB1.L.
- 1.2 Clamp on the jig with the joint between EB1.L and SB1.L accurately located on the joint centre-line of the jig.
- 1.3 Bolt together verticals EV1.L and SVL1.L and locate on jig. Tack weld EV1.L to EB1.L and SVL1.L to SB1.L.
- 1.4 Measure and cut the outside face diagonal ED and tack weld in position on the End Panel gussets.
- 1.5 Unbolt joint and remove End Panel E1.L. Fit deck-side diagonal and complete welding of all joints.

STEP 2: Assembly of Side Panel S1

- 1.1 Bolt together Side Panel Longitudinals, SB1.L and SB2.L with Joining Bracket J2.L.
- 1.2 Clamp on jig with joint accurately located on the joint centre-line.
- 1.3 Rest Top Longitudinal ST1.L on the raised supports on the jig with the gussets resting on the supports and the mitre joint with the left side vertical aligned for welding.
- 1.4 Bolt together verticals SVR1.L and SVL2.L. Locate on jig with lower end lined up with the joint of the bottom longitudinals and the top end lined up for the mitre joint with the top longitudinal. Tack weld all the joints.
- 1.5 Measure and cut the outside face diagonal SD and tack-weld in position. Note that the upper end rests on the gusset and has a short length of 40 x 40 x 6 angle to link it to the angle pc of the Top Longitudinal.
- 1.6 Unbolt joint and remove Side Panel S1.L. Cut the deck-side diagonal noting that this fits directly against the angle piece of the Top Longitudinal. Fit in position and fully weld all joints.

STEPS 3 to 9: Assembly of Side Panels S2 to S9

Repeat procedure of STEP 2 for each pair of Side Panels in sequence working towards the right hand end.

STEP 10: Assembly of Side Panel S10.L and End Panel E2.L (Right Hand End)

- 10.1 Bolt together Bottom Longitudinals SB10.L and EB2.L with Joining Bracket J11.L.
- 10.2 Clamp on jig with the joint accurately positioned.
- 10.3 Locate Top Longitudinal ST10.L in position on supports, aligning mitre joint with SVL10.L.
- 10.4 Bolt together Verticals SVR10.L and EV2.L and locate on jig lining up joints to top and bottom longitudinals. Tack weld bottom ends to their respective Bottom Longitudinals. Tack weld verticals for Panel S10 to Top Longitudinal.
- 10.5 Measure and cut outside face diagonals SD10 and ED2 and tack weld them in position on the Side and End Panels respectively.
- 10.6 Unbolt joint. Complete Side Panel S10.L and End Panel E2.L by fitting deck-side diagonals and welding up all joints.

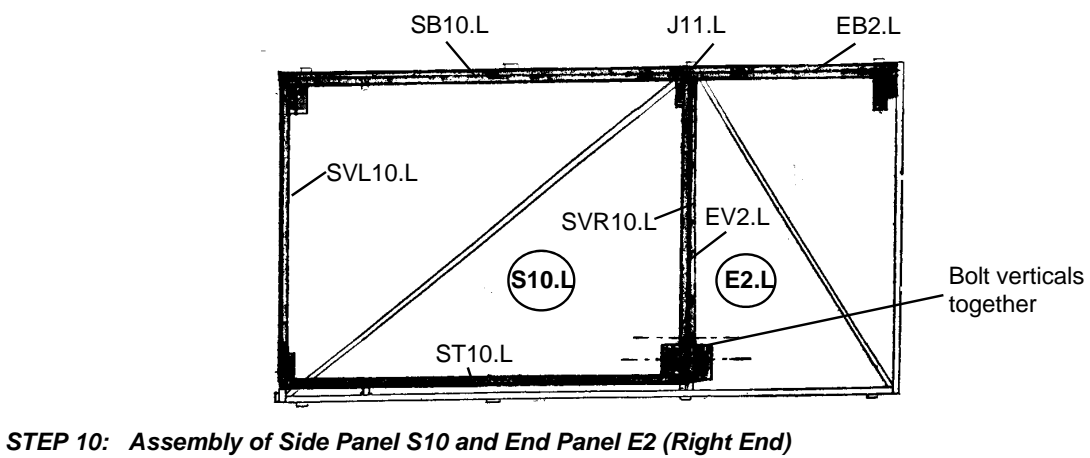
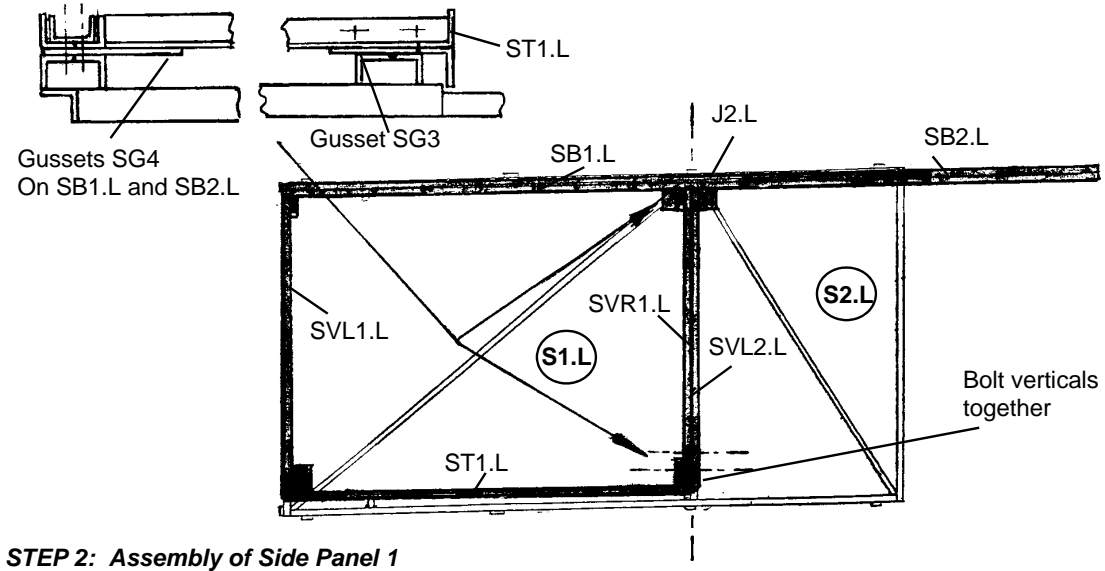
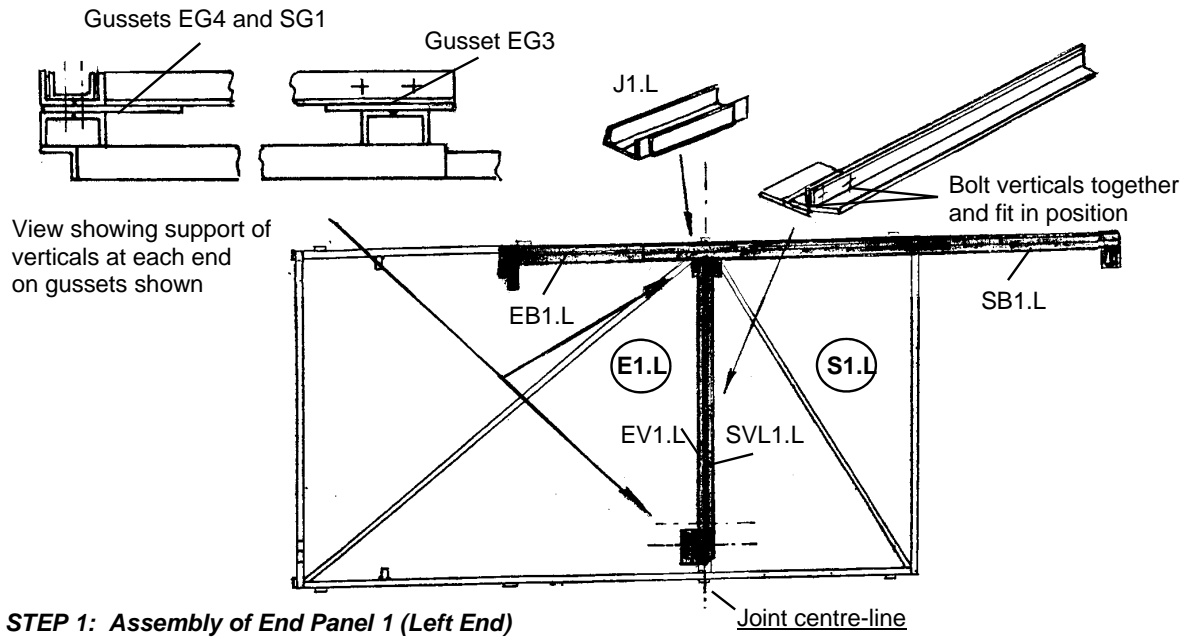
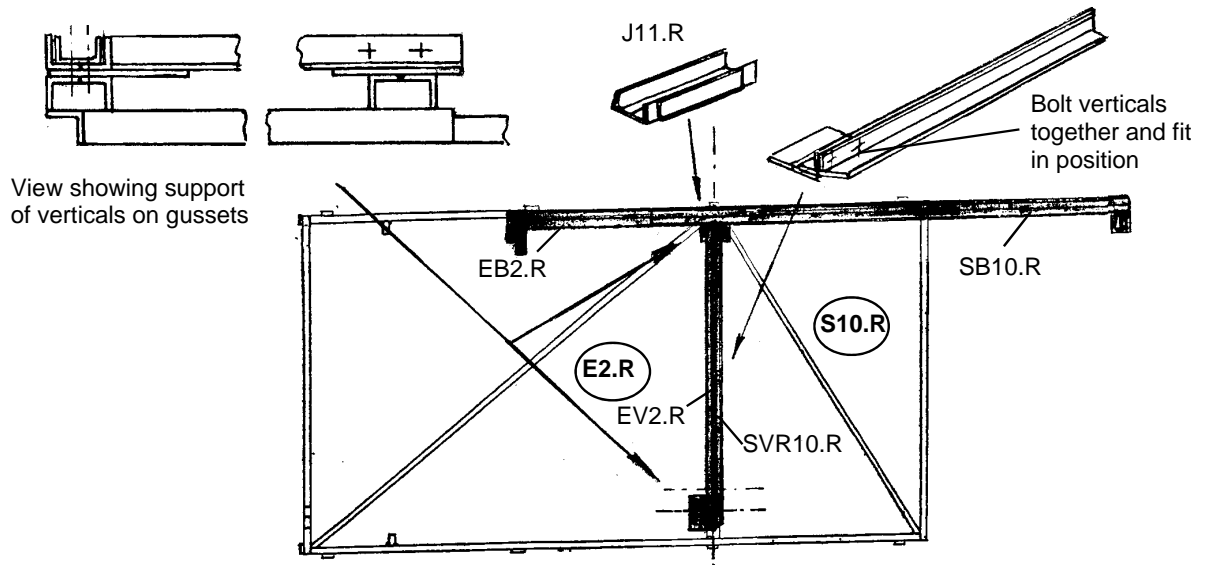


Figure B14: Assembly of Side Panels (Left Side)

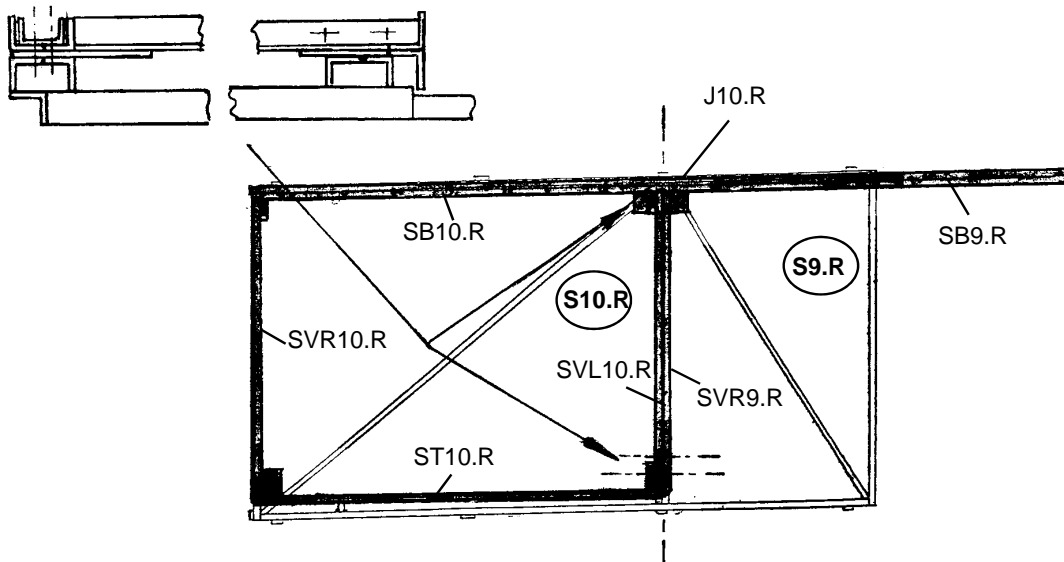
STAGE 5.3: Assembly of Side Panels (Right Side)

This follows the same procedure as for the Left Side panels but starting from the Right Hand end and then working in sequence to the Left Hand end.

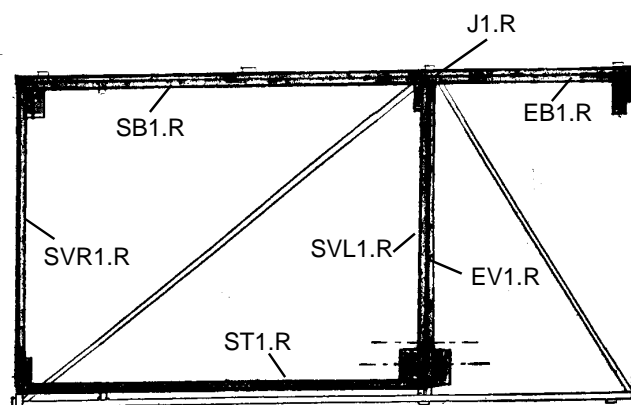
Therefore STEP 1 is the assembly of the right hand End Panel 2 and Step 10 the assembly of Side Panel 1 and Left hand End Panel 1.



STEP 1: Assembly of End Panel 2 (Right hand end)



STEP 2: Assembly of Side Panel 10



STEP 10: Assembly of Side Panel 1 and End Panel 1 (Left Hand end)

Figure B15: Assembly of Side Panels (Right Side)

STAGE 6: Assembly and Testing of Footbridge

When all panels have been completed the footbridge should be fully assembled at the workshop. This has three purposes:

1. To ensure that all panels bolt together before transporting the footbridge to site.
2. To complete the construction of the footbridge by adding the bearing feet at each end and the stiffening braces for the verticals.

The bearing feet are best fitted when the bridge is assembled to ensure that they sit evenly on the ground. The stiffening braces are best fitted after proof testing so that they are not in the way of the footbridge deflection whilst testing.

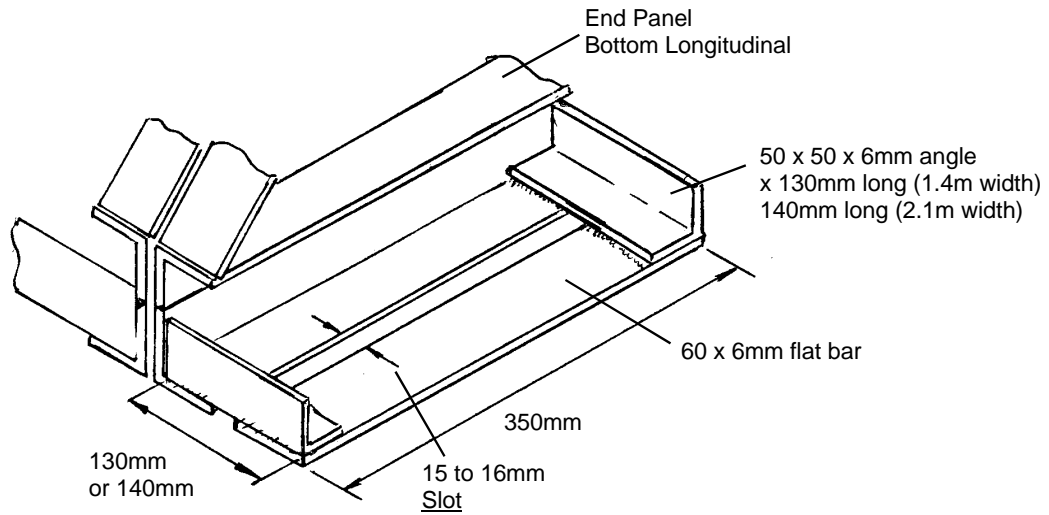
3. To proof test the footbridge (see Section 5.2.7)

6.1 Fitting Bearing Feet

The construction is shown in Figure B16. A bearing foot is required at each side at each end of the bridge, 4 in total.

6.2 Fitting the Stiffening Braces for the Verticals

The details of the Stiffening Braces are shown in Figure B.17. At each module joint a cross-beam is clamped under the bottom longitudinals to which are bolted angle braces to the Verticals on each side of the footbridge. The braces provide sideways support to the pair of verticals that are bolted together at each joint.



Bearing Feet at each end corner of bridge

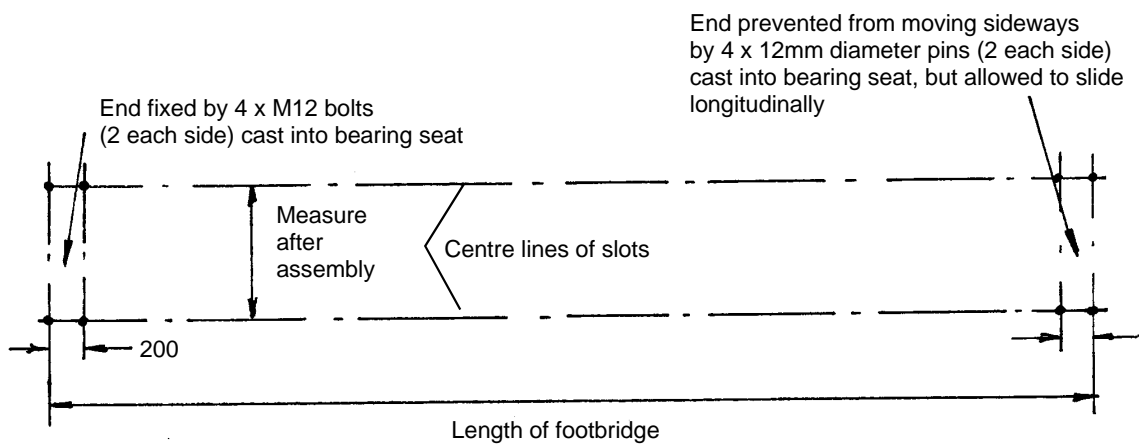
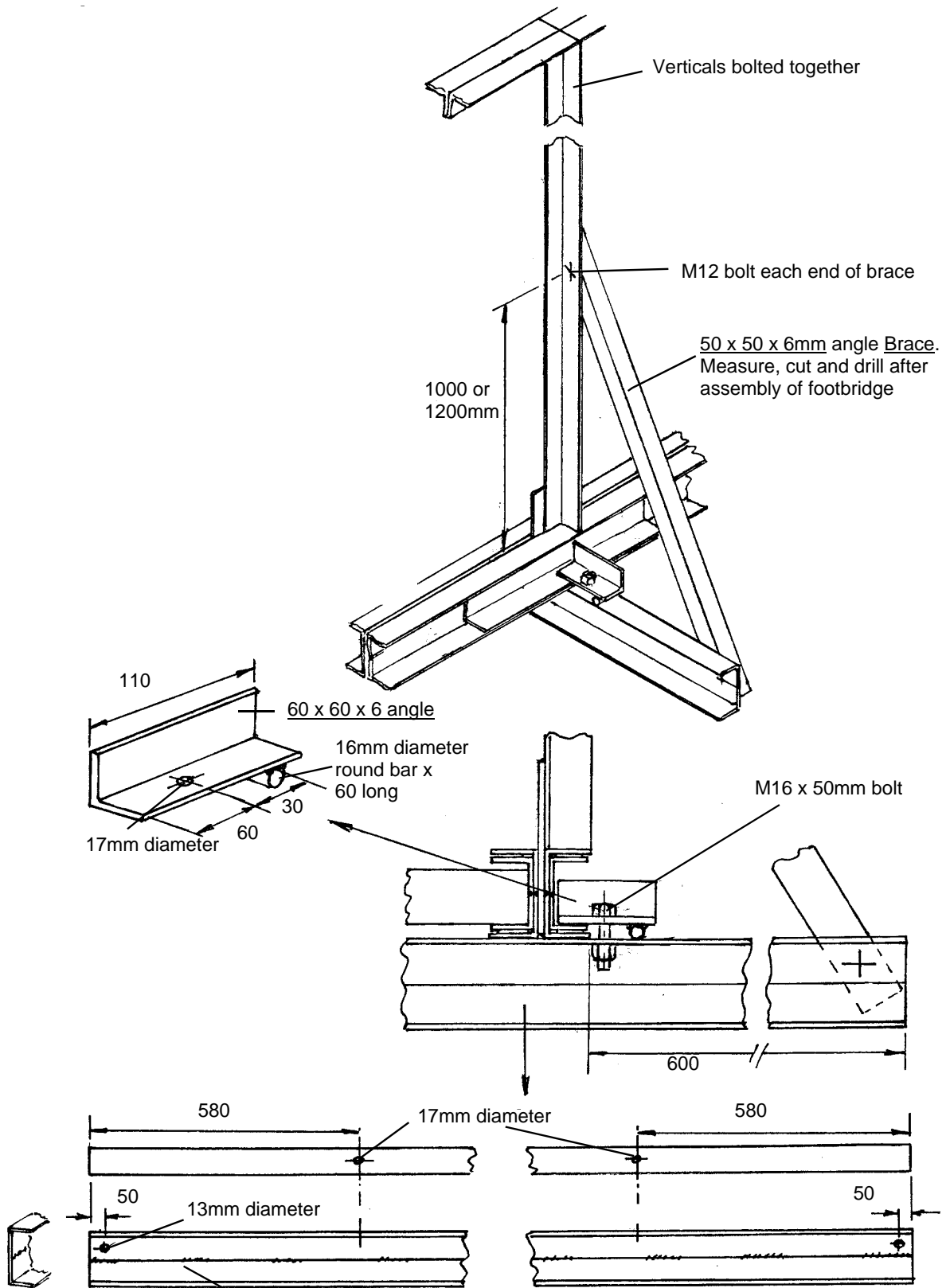


Figure B16: Bearing Supports and Anchors for Footbridge



Channel made by stitch welding together 2 pcs of $60 \times 60 \times 6$ mm angle. Measure and cut after assembly of bridge. Note: it protrudes 600mm each side of bridge.

Figure B17: Details of Stiffening Braces for Verticals

APPENDIX C

CONSTRUCTION OF A FOOTBRIDGE USING A SCRAP TRUCK/BUS CHASSIS¹

Figure C1 shows the details of a footbridge that uses 2 scrap truck chassis as the support beams for the deck. The footbridge has a total span of 21.7m with a central concrete pier where the chassis meet.

Figure C2 shows a typical scrap chassis. They are reasonably common in some countries and can provide low-cost steel beams for construction of a cost-effective footbridge. The depth of the beams needs to be at least 180mm with a metal thickness of 8mm for a span of 10m.

A chassis may need some straightening and repair or replacement of cross-members to make it suitable for a footbridge.

The basic construction of the footbridge of Figure C1 is shown in Figure C3. The deck and guard rails are supported by 150 x 75mm timber cross-beams resting on the chassis at 1m intervals. The cross-beams need to be fixed on the chassis. Figure C3 shows one method in which angle brackets are welded to the chassis and the beams screwed to the brackets. Other methods are possible.

The deck comprises sheets of 3mm thick steel that rest on the cross-beams. The joints are sealed by 50 x 25mm strips of treated timber nailed to the cross-beams through holes drilled in the sheet.

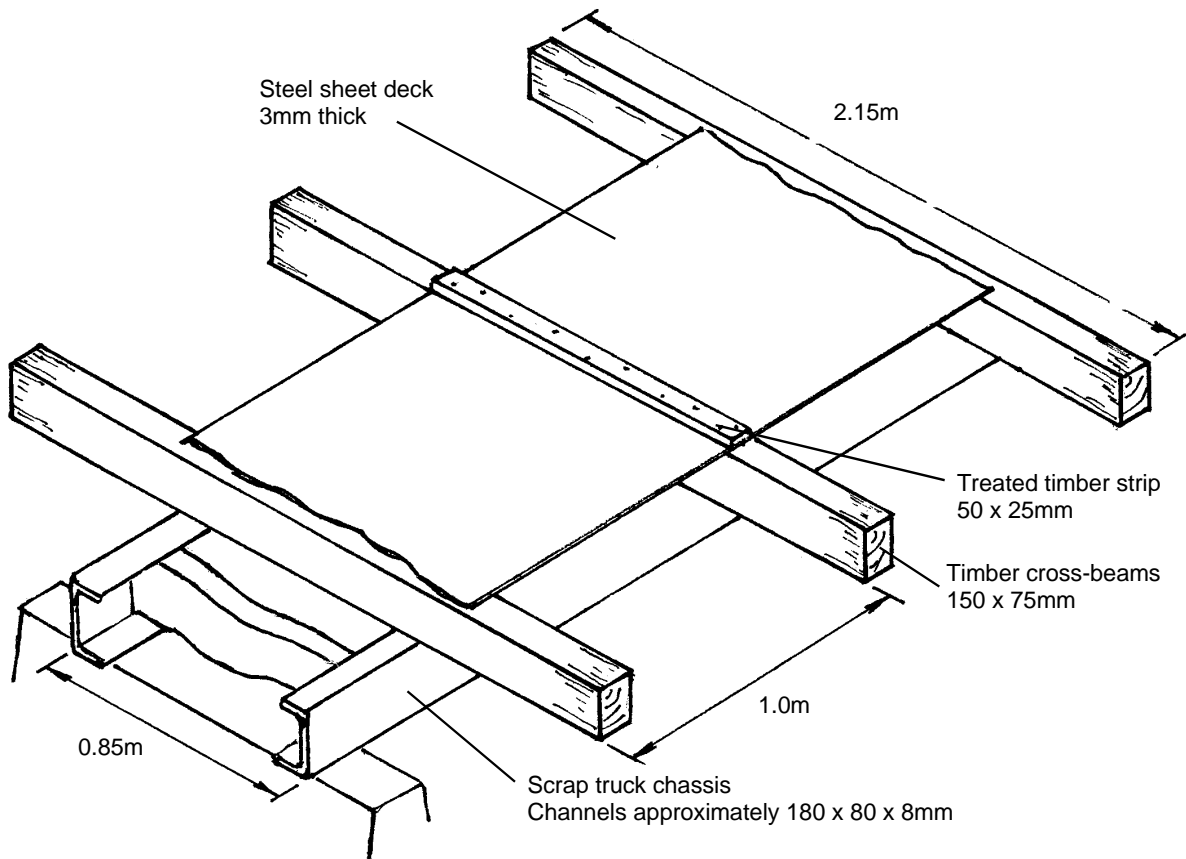
¹ Information and photographs provided by the Kisii Training Centre, Kenya.



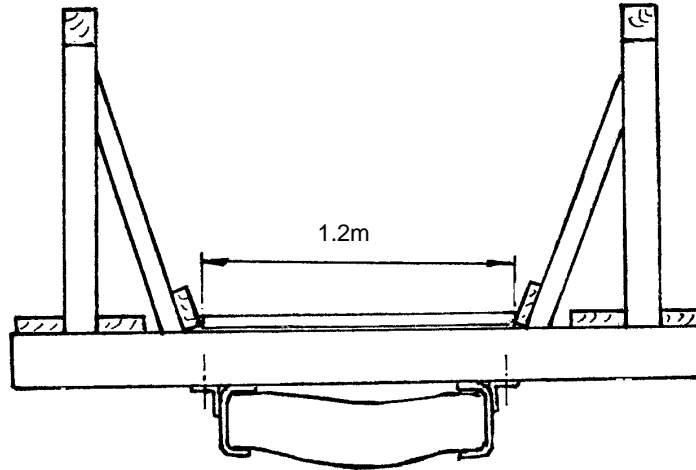
Figure C1: Footbridge Using a Scrap Truck Chassis for the Beams Supporting the Deck



Figure C2: Typical Scrap Truck Chassis



Details of Structure



Cross-Section of Footbridge

Figure C3: Construction Details of Footbridge with Scrap Truck Chassis Beams

APPENDIX D

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- ***Countryside Commission of Scotland:***

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- ***Developing Technologies:***

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- ***ILO/ASIST:***

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- ***Outdoor Structures Australia:***

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- ***SKAT Foundation:***

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- ***Trail Bridges in Nepal:***

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Email - tbs@nepaltrailbridges.org

TBSSP (Trail Bridge Sub-Sector Project), HELVATAS Nepal, Swiss Association for International Cooperation, P.O. Box 688, Kkathmandu, Nepal
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